Post War Artillery Materiel: Telescopic Musket Sights

ARMY ORDNANCE

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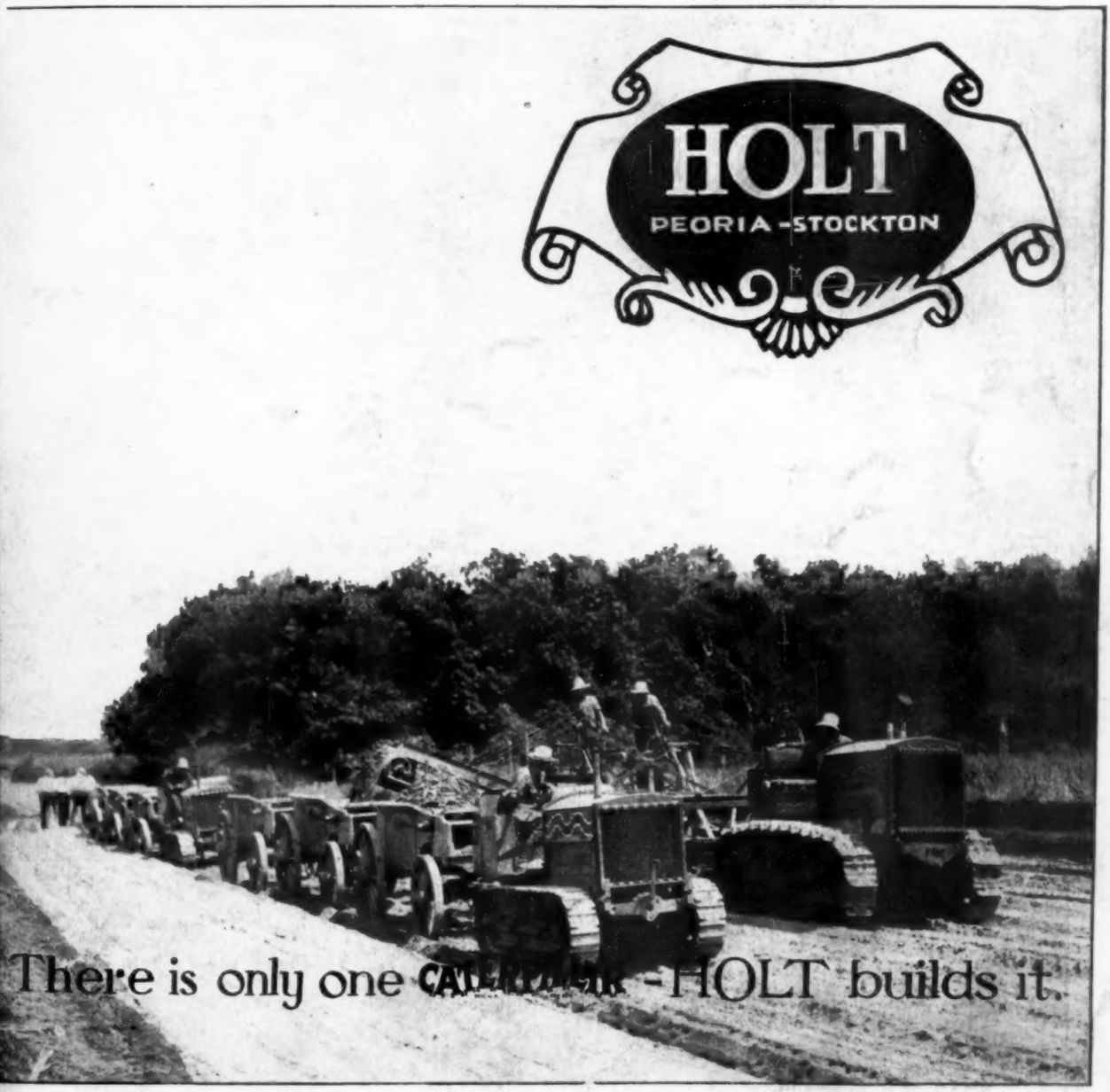
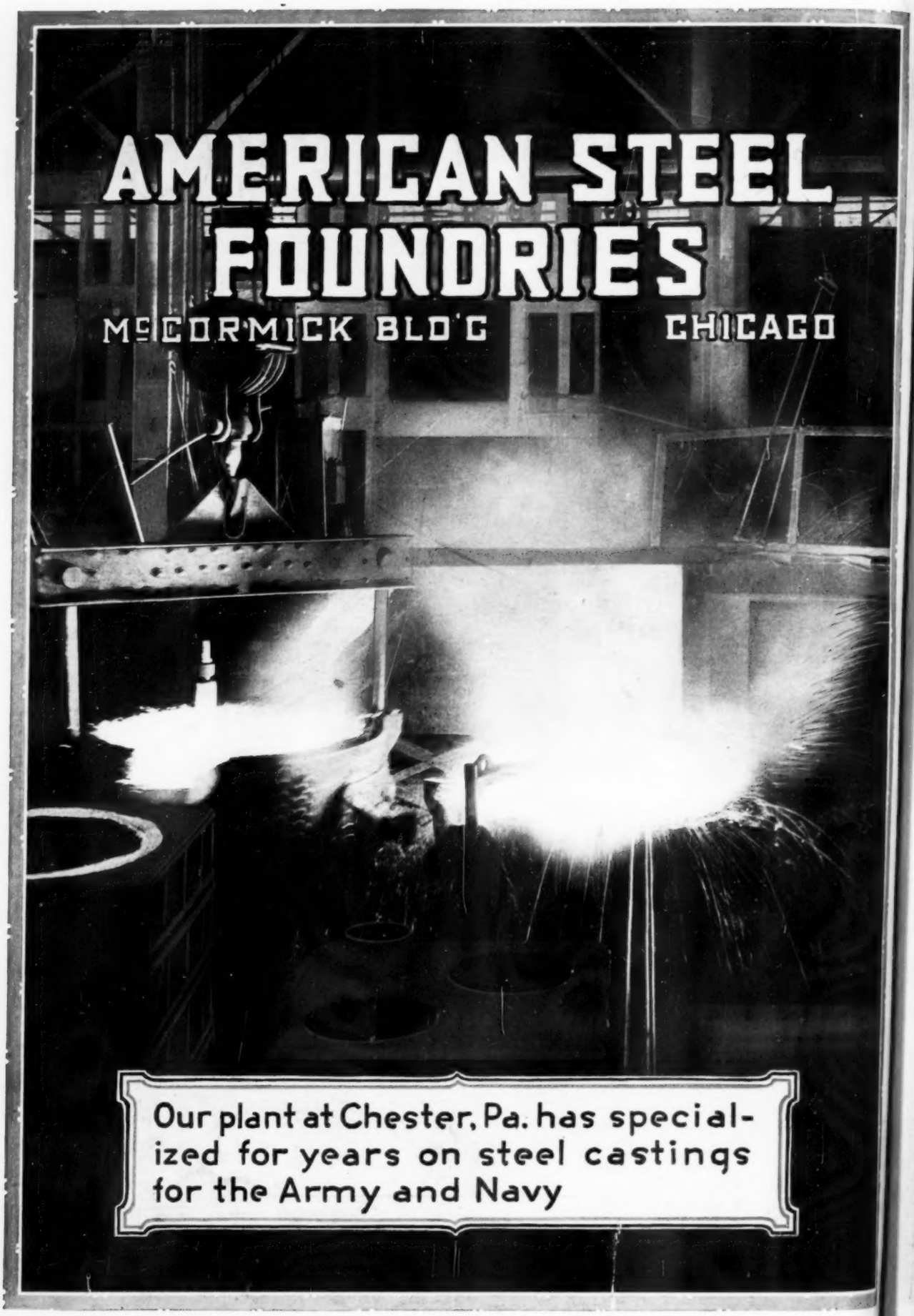


THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Third Annual Meeting, Aberdeen Proving Ground, Md., Friday, October 7, 1921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Published bi-monthly by the Army Ordnance Association at 410 Munsey Building, Washington, D. C. Subscription, $4.50 per annum in advance. Advertising rates on application.

Entered as second-class matter August 14, 1920, at the post-office at Washington, D. C., under the Act of March 3, 1879.

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Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized September 17, 1920.

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HOLT CATERPILLAR MOUNT
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Post-War Artillery Materiel

By

G. F. JENKS

Member A. O. A.

ALL wars stimulate the development of artillery materiel. The ingenuity of a nation in arms is taxed to the utmost to develop some method or some implement of war which will overcome the enemy. New ideas are developed and current inventions are adapted to meet the needs of warfare. At the same time, the ideas and materiel developed during years of peace are put to the supreme test. The service and the scientific and engineering world are converted into enormous proving grounds and research laboratories for the development of war materiel. With the advent of peace the nation at large revolts at the thought of the economic waste and human sacrifice of war. The artilleryman and the ordnance engineer once more take up the problem unaided to apply the lessons taught on the battlefield.

Colonel Jenks

Fortunately, at the close of the World War, the ideas of the service and of ordnance engineers crystallized in a definite program for the development of Mobile and Railway Artillery contained in the Westervelt Board report. The line of progress of seacoast materiel seemed clear and was incorporated into Board of Review projects.

The service demands during the war specified increased mobility, increased range and increased power. These demands have multiplied since the armistice and now include higher road speeds, unlimited field of fire and interchangeability of mounts. The prime characteristic which the ordnance engineer must keep in mind is producibility.

In divisional artillery greater mobility was sought during the war by the development of the tractor to replace the horse, of the medium and heavy artillery by the use of tractors, and for the heaviest artillery by the mounting of guns on railway mounts. Both our own and the French engineers sought the ideal mobility in motor mounts—the caterpillar or self-propelled mounts. The development of the motor mount is the most revolutionary and the most promising field. Through it not only increased mobility but mobility at higher speeds are attainable.

Increased range is attained both through projectile development and the use of higher muzzle velocities. Powder pressures remain the same. The gun has been lengthened for the higher muzzle velocity. For lightness of construction in these longer guns, three methods of gun construction are being tried out—first, the built-up construction employing steels of higher physical characteristics than used before; second, the wire-wound construction; and third, the autofrettage construction.

In the present design of artillery materiel the engineer must predict what materials will be available for use in the future. There are no present production programs. Our storehouses are full of artillery. The problem is the development *now* of a type of artillery which will be satisfactory in a future emergency and producible *then* with the facilities which will then exist and according to the art and science of that future day. There will be no time when the emergency of war comes to develop new types or designs of materiel. That work must be done now. But peace-time requirements of the industrial world will demand the use of higher grade materials and improved methods of production. They will be available for war production of future decades. In gun construction the logical step ahead is the development and use of higher grade steels.

The nickel steel specified during the war was of the following physical qualities: Elastic limit, 65,000; tensile strength, 95,000; elongation, 18 per cent; contraction, 30 per cent. Gun forgings for some experimental materiel are being made of a nickel-chrome steel with the following physical qualities: Elastic limit, 80,000; tensile strength, 105,000; elongation, 18 per cent; contraction, 30 per cent. Such forgings have been produced, but many problems have arisen in their production. Some of the first made were extremely brittle, and under stress behaved like cast-iron. One small gun which seemed to be made of excellent metal according to the usual methods of test, failed under less

than service interior pressure. Impact tests developed the fact that an improper heat treatment had been given. This brittleness has apparently been overcome by quenching the forging from the "draw." But, although excellent impact tests have thus been obtained, the metal is full of internal stress and the gun finisher has in some cases found it impossible to keep the bore straight. It is hoped to relieve these internal stresses by additional heat treatment. Laboratory tests made upon the steel of captured German guns indicate that this kind of steel was used successfully and that it was tough, free from internal stresses and remarkably uniform. Because of the difficulty in working nickel-chrome steel and its sensitiveness to heat treatment, other alloys will probably be tried out, but without compromising the physical qualities by tensile tests.

No attempt is being made to use the higher grade steels for seacoast gun construction.

No new problems are involved in the construction of the wire-wrapped gun. By the use of wire, lower grade metal can be utilized in the forgings. The weight of the guns made by this process is slightly more than that made of chrome alloy steel. At present, however, it is a more conservative method of construction.

In the auto-frettage method of construction, the gun is built up of few pieces of steel of medium physical qualities. The walls of the gun are internally stressed beyond its elastic limit by internal hydraulic pressure. The condition set up is similar to that produced by the shrinking process. It can be applied to the whole gun, whereas the effect of shrinkage is limited to the hooped portion. For given strength of metals and bore pressure, thinner walls are sufficient. This assures minimum weights. The process is also a cheaper one than either the built-up or the wire-wrapped method of construction.

During the war, the service demanded guns of 192 mm. and howitzers of 240 mm. caliber for use on mobile mounts and 14-inch guns and 16-inch howitzers on railway mounts. For the 14-inch guns alone a $50,000,000 plant was under construction, and other large plants would have been required for the gun mounts. The only limit to the caliber and size of artillery demanded has been the capacity of the country to design and to produce pieces that could be used in the field.

The Allies were forced to adopt the same policy and even constructed guns in which the jacket was removed from the tube for transportation. The same demands will exist in the next war of the first magnitude. It may be argued that the real work in battle is accomplished by the divisional calibers, but as long as the spirit of competition exists in the minds of men, so long will the artillery commander demand the services of the heaviest pieces of artillery that the country can make and transport to the battle line. No development of aircraft or of other auxiliaries of warfare now practicable can render obsolete or replace the heavy caliber.

The largest calibers it appears practicable to mount today on motor mounts are the 240 mm. howitzer and the 8-inch gun. Studies made indicate that a 35-caliber howitzer giving a range of 25,000 yards, or an 8-inch 50-caliber gun giving a range of 35,000 yards can be mounted in units not exceeding 40 tons weight. The motive power would be furnished by a gas-electric set and the caterpillar tracks would be motor driven. The largest calibers being mounted on railway mounts are 14-inch 50-caliber guns and 16-inch 25-caliber howitzers. These are the largest pieces that it seems practicable to transport on their mounts in single units. If 16-inch guns were so mounted, it would be necessary to transport the gun separately from its mount and to assemble it at the emplacement. Such a method may be feasible. For seacoast fortifications no pieces of greater than 16-inch caliber are now under construction, although the department has recommended that Congress appropriate money to inaugurate the manufacture of a gun of at least 18-inch caliber.

The Westervelt Board report approved May 25, 1919, specifying increase in the speed of tractors and motor mounts, placed 12 miles per hour as the maximum speed for light motor mounts and 6 miles for the heavy ones. It considered that a speed of 15 miles could be reached on rubber-tired wheels only. The limits imposed by that report are already obsolete. 75 mm. gun motor mounts of the track laying type have already been operated at 25 miles per hour, 155 mm. gun motor mounts on rubber wheels at over 15 miles. It can now be asserted that the 155 mm. gun motor mount of the track laying type will be capable of 15 miles per hour on roads or turf. These speeds are accomplished by means of rubber bearings or cushions on wheels and track, and by the liberal use of engine horsepower, 270 in the 155 mm. mounts of the track laying type.

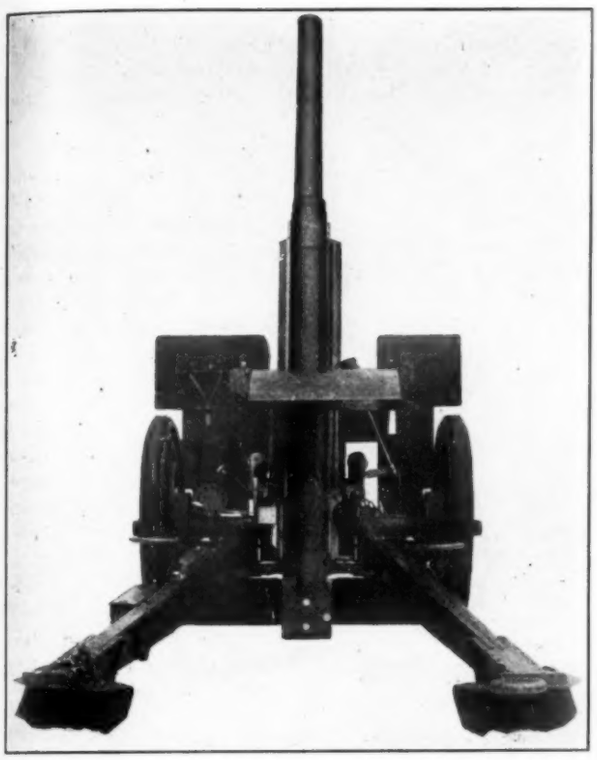
Unlimited field of fire is being attained at present only in anti-aircraft motor mounts and in railway and seacoast mounts. Thirty to 60 degrees traverse is practicable in wheel mounts of the split trail type and about 10 degrees in wheel mounts of box trail type and from 10 to 25 degrees in motor mounts. Greater traverse in motor mounts may be accomplished by maneuvering the complete mount by hand power or engine power. Unlimited traverse in motor mounts can, of course, be obtained at the expense of weight, mobility and stability, but at the present stage of development it is not warranted.

Elevation up to 80 degrees has been insisted upon by the service and incorporated in the 75 mm. field gun and 65 degrees in guns up to the 155 mm., and in howitzers to include the 8-inch. For seacoast guns on fixed mounts, the policy is to give the maximum elevation and traverse that could be used in the service. But for mobile types this specification has been coupled with one limiting the recoil of the gun to the ground line.

The condition of high elevation and minimum depth of pit has necessitated placing the center of the trunnions of the tipping parts in rear of their center of gravity and equalizing the forces required to elevate and depress by an equilibrating system. In most pieces it requires variable recoil. Although the equilibrating system adds weight and complexity to the gun carriage, yet it tends to improve the accuracy of fire as the pressure on the elevating gearing does not change in direction during recoil. This should hold the backlash in the same direction and reduce the jump.

Bringing the center of rotation of the gun to the rear and the use of variable recoil also permits lowering the axis of the gun. This is advantageous in permitting the shortening of the trail and lightness of construction.

Wide traverse has resulted in the use of the split trail at the expense of weight and simplicity of construction. The split trail 75 mm. materiel weighs over 500 pounds more than the box trail materiel. This is due partly to the greater elevation—80 degrees compared with 45 degrees. It is believed that the simpler, lighter, and more rugged single trail is by far the preferable design for the 75. For calibers of 4.7 inches and above the wide traverse ob-



75-mm. Gun Carriage, Model of 1920 (showing gun at 80° elevation)

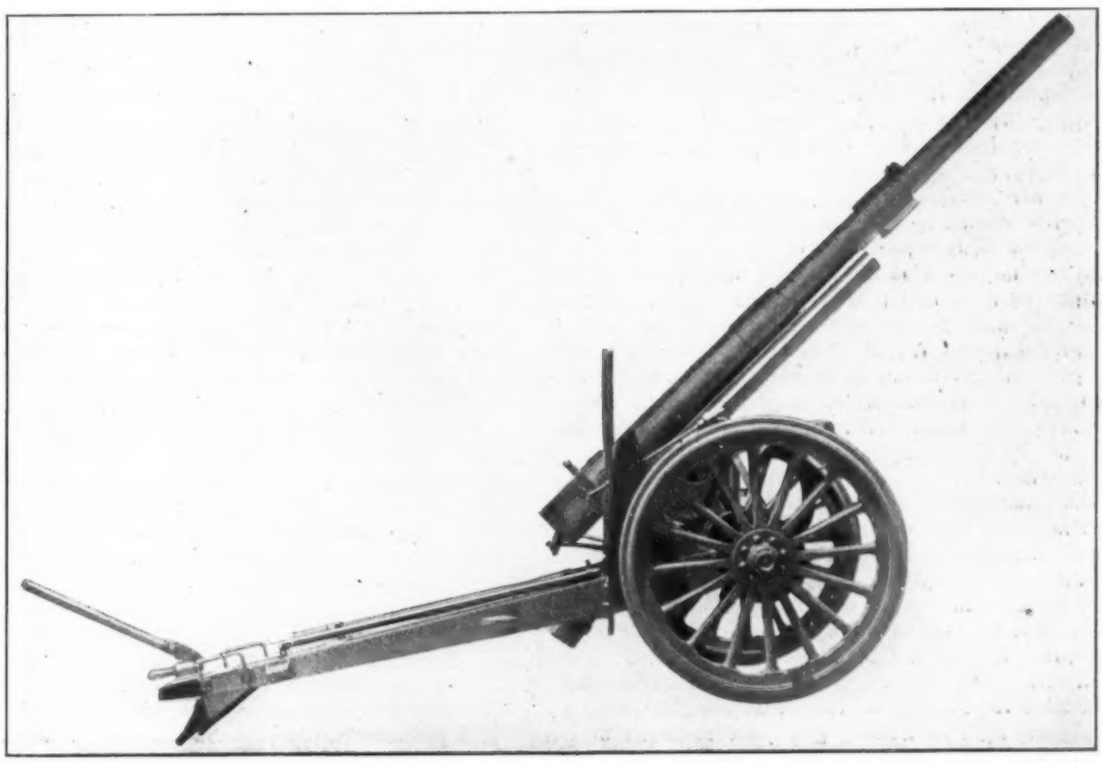
tained by the use of the split trail is deemed essential.

The provision for elevating pieces beyond that required for maximum range is causing complication of design and increased weights. The bottom carriages must be built out farther from the axle to permit clearance at high elevation. This is expensive in weight.

The demand for elevation in mobile artillery beyond that required for the maximum range is believed to be unjustifiable. If increased angles of fall are needed, reduced charges can be used. If it is contemplated using the 75 against aircraft it should be remembered that no provision is made for cross levelling the carriage or for efficient sighting on aircraft. In later studies of 75 mm., 105 mm., 4.7 inches and 240 mm. calibers, the elevation is being limited to that required for the maximum range. It is believed that these higher and simpler designs will win greater approval from the service.

The Westervelt Board report contemplates a gun and a howitzer capable of being mounted on the same carriage. This simplifies direction and supply, but it complicates the design of the carriage. It is difficult to secure the same reactions on the carriage from both gun and howitzer. For example, the 4.7-inch gun materiel is much heavier than it need be because the 155 mm. howitzer requires a heavier carriage. It appears preferable not to attempt to use exactly the same carriage for both pieces but merely to make them as nearly alike as practicable. The ideal of the artilleryman is the reduction of calibers to a few and the standardization of mounts. The desirability of such a program is apparent to the supply department charged with production and maintenance. However, the mission of the piece, not the desirability of standardization, must fix its characteristics. In the latest studies the requirement of interchangeability is being departed from in both divisional and corps artillery.

No marked development is being attempted in sighting systems. Of course, panoramic sights or suitable tele-



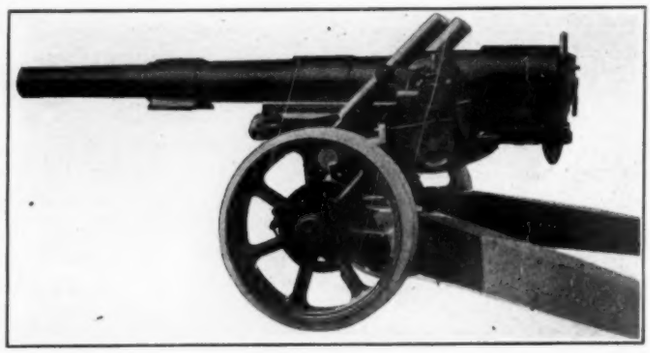
75-mm. Gun Carriage, Model of 1921

scopic systems will be used for all calibers. The field gun sight follows that developed for the model of 1916 materiel; for heavier mobile guns quadrant sights with panoramic telescopes will be used. For accompanying fire control instruments for mobile artillery no marked improvement in design is contemplated.

The hydro-pneumatic recuperator is standard for pack howitzers and larger pieces. The St. Chamond type is used for 75 and 105 mm. calibers and the Filloux type for 4.7 to 8-inch calibers. No new developments in these mechanisms have been made since the armistice. They have been merely adapted to meet the new conditions imposed.

During the war great difficulty was encountered in the manufacture of recuperators. Because of the use of oil and air under high initial pressure extremely fine workmanship was required in finishing the bore of cylinders and in the manufacture of pistons. If possible a recuperator which is simpler to manufacture should be developed.

As indicated above, the development of light and heavy artillery up to 8-inch howitzers includes two types: the wheeled type and the motor or caterpillar type. The design of the wheeled type is more highly perfected through long experience. The lesser importance given weight has permitted extensions of both vertical and horizontal fields of fire. No large development of this type of mount should be expected in the future.



155-mm. Howitzer Carriage, Model of 1920

On the other hand it is probable that we have overstepped the limit of conservative design and that we will be content to reduce the severity of some of our specifications in order to simplify and lighten the design. However, the present designs incorporate characteristics which seem desirable and until pieces embodying those ideal characteristics shall have been constructed and tested, it will not be possible to determine what characteristics are feasible.

In the war models of motor mounts, little attention could be given to reduction of weight and refinement of design. The possibilities of development of this type of gun mount should not be judged by the materiel built under war contract nor even by that now being constructed. Such essential characteristics as accessibility of parts for maintenance and elimination of mechanical weakness in the details of construction especially must be worked out by experience. In considering any model, the possibilities of perfecting the design into a desirable machine must be given the greatest weight. Mechanical imperfections can be eliminated.

Motor mount development is now proceeding along two lines: first, the track laying type found in tractors, and, second, a combination wheel and track laying type in which the mount may be operated on wheels on good roads or on tracks where road conditions are bad.

Both types are self-propelled and have similar gun characteristics. Weights are about the same. Recent developments of the first named type indicate that speeds will be about the same on good roads. Because of the promise of both types, light and heavy gun pilot materiels of both are being built. Seventy-five and 155 mm. gun and 105 mm. howitzer materiels are being designed and built by the Holt Manufacturing Company and by the Front Drive Motor Company. Good comparative tests of the two principles of construction should be obtained from these pilots.

Four 155 mm. gun caterpillar mounts designed by Mr. Christie of the Front Drive Motor Company have been completed for a service test. Eight caterpillar mounts for the same gun, made according to the Holt design are now in the hands of the service. No decision should be drawn, however, from a comparative test of these two current models as the Holt Company is now designing and constructing an improved mount in which weight and speed characteristics will be about the same as in the Christie mount. For the 4.7-inch gun and 155 mm. howitzer, the Holt type only is being developed at this time. A road speed of 18 miles per hour is expected. The Westervelt Board report specified 8 miles. The pack howitzer developed is promising, but will need important redesigning before it is fit for service tests. In it are provided axial traverse and a sufficient recoil and length of trail to secure stability. Some parts are a little too heavy for mule transportation but their weights can probably be reduced without great difficulty. The current pilot is capable of being neatly packed for mule transportation.

In the infantry accompanying howitzer, an attempt is being made to develop a piece which can be used either as a direct fire gun against tanks or as a howitzer, taking the place of the 3-inch trench mortar. Guns of both 1.8 inch and 2.24-inch caliber are under construction. The caliber suitable for an anti-tank gun is too small for an efficient howitzer projectile. It is believed more logical to recognize the difference in mission of the two pieces and to develop efficient designs for both missions. The piece under test will be capable of being broken up into man-loads.

For anti-aircraft materiel the development of a satisfactory fuze for high muzzle velocities is a limiting factor. Two calibers of guns are being developed, 3-inch and 4.7-inch. The mounts will be capable of being levelled on the base of the motor mount. The sighting system permits the application of azimuth and elevation corrections and super elevation without disturbing the pointing of the sight. Compressed air will be used for loading. A fuze setter will be attached to the gun for setting the fuze just prior to loading. In the heavier gun a muzzle brake is being developed in order to lessen the load on the recuperator. With other guns, almost 85 per cent of the recoil energy has been absorbed in a muzzle brake but only about half that efficiency is expected in this case. For anti-aircraft work, however, the big problem is to develop a satisfactory sighting and fire control system.

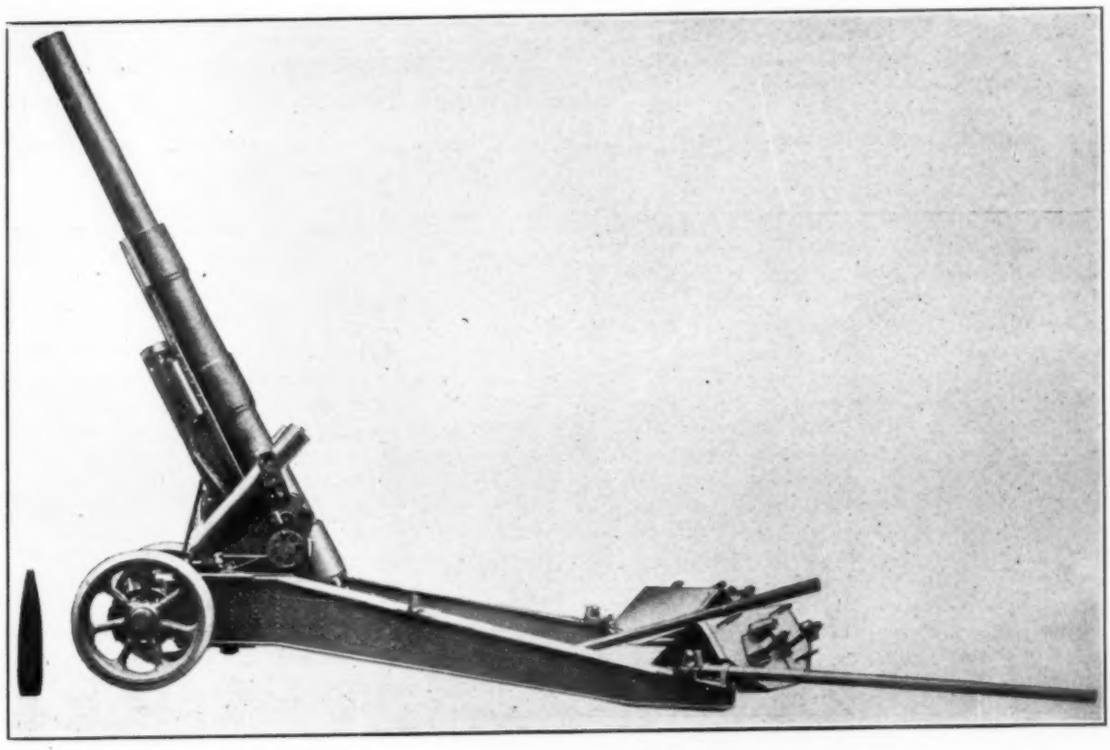
Anti-aircraft fire control developments are at present following the French and British war development. A further perfection of this apparatus will probably involve complicated apparatus operated and controlled electrically. It is possible that considerable advantages may be obtained

Sight for 75 and 105-m.m. Materiel, Model of 1920

through the use of such instruments. Their use, however, will require a large amount of work and instruction in the service if they are to be maintained in serviceable condition and their operation is to be successful. Notwithstanding the fact that the service has reported difficulty in maintaining such ordinary standard articles as storage batteries and voltmeters, it is believed that a service with the technical education and experience of our artillery should successfully employ such mechanisms. The recruit of the future will be more readily trained to operate and care for complicated instruments than in the past.

For coast defense work, the 16-inch, 50-caliber gun and the 25-caliber howitzer are now standard. Only one disappearing carriage for the gun has been built. Both guns and howitzers will be mounted on barbette carriages capable of 65 degrees elevation. Hydro-pneumatic recuperators permit this use of increased elevation. The 14-inch, 50-caliber gun is also standard for coast defense. For it a new type of railway mount suitable for both field and coast defense work is under manufacture. For coast defense a concrete foundation permits of 360 degrees traverse, while for field work traverse can be obtained from a curved track. The same railroad mount will take the 16-inch howitzer. A railway mount for a 12-inch 20-caliber howitzer has been under test. The howitzer is capable of all-round fire from the car body. The same type of carriage can be developed for a 8-inch 50-caliber gun, but lack of funds has not permitted the undertaking of this work. Sights will permit of both direct and indirect fire.

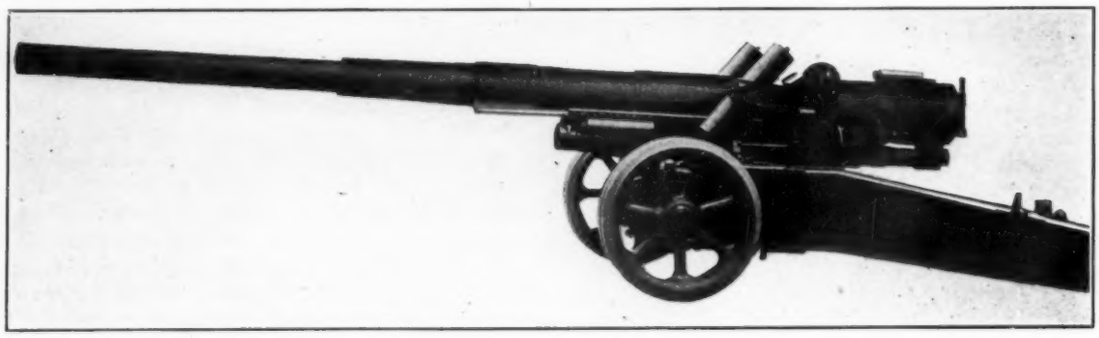
The present tendency is toward more powerful guns for seacoast defense. Some gain in power may be obtained by increasing the length and muzzle velocity, but the logical step is an increase in caliber. If economy is to be exercised in the construction of fortifications they should be armed with guns which are at least two decades ahead of naval armament in development.



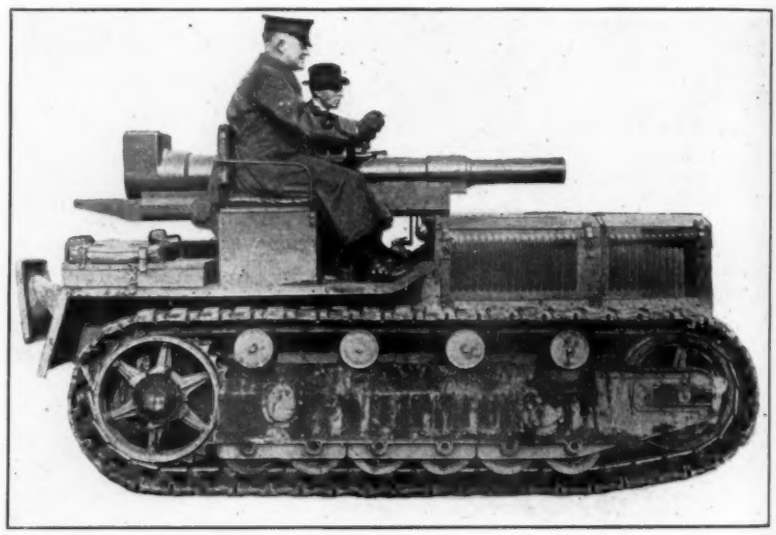
8-inch Howitzer Carriage, Model of 1920

A large problem is the development of fire control materiel for heavy coast guns. Range finding and observing instruments set up in the neighborhood of the battery are insufficient. Guns are now capable of reaching targets which are below the horizon from our present fire control stations. The observer is forced into the air, where the difficulties of levelling and orienting instruments are tremendous. An observation instrument levelled and oriented by gyroscope has been completed. It is rather complex and no hope can be given as to its satisfactoriness. In the development of accessory instruments good progress is being made.

This rapid general survey indicates the enormous extent of the field in which artillery development work is required. It is impossible in a single article to indicate the depth of the program by touching upon the numerous problems which the research engineer must solve in the laboratory. Needless to say, years of intensive work is required. As the stock of artillery materiel on hand is sufficient for any present need, time should be available to perfect materiel and thoroughly test it before production should be required. Only an engineer familiar with the cost in the past of putting types of materiel into production before the design has been carefully tested at the proving ground and in the field can realize the enormous saving to the government of fully developing artillery materiel on a small scale before equipment of armies is required.



155-mm. Gun Carriage, Model of 1920

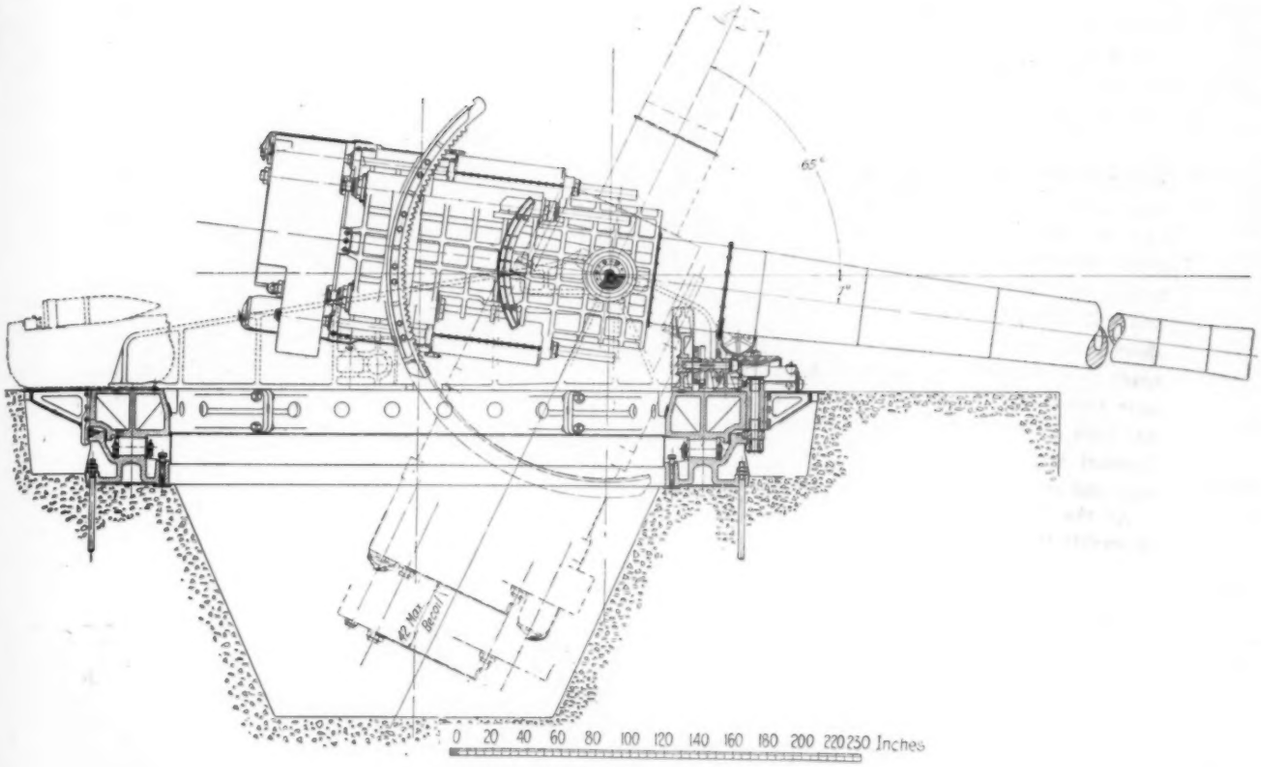


Holt Motor Materiel, Mark VI for 75-mm. Gun and for 105-mm. Howitzer, Model of 1920

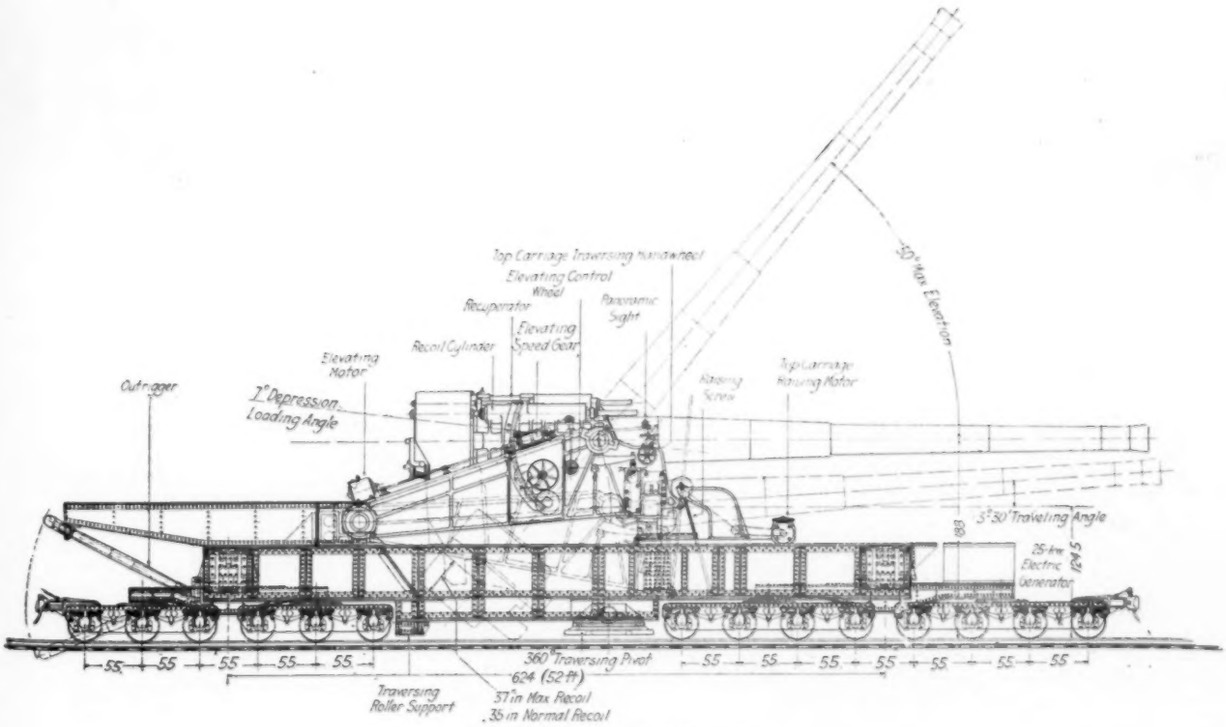
Christie Motor Materiel for 155-mm. Gun, Model of 1918

Never before has the Ordnance Department been called upon to design and develop such an enormous variety of materiel in such a short time. It has not been possible to perfect and check designs as carefully as when the yearly design program consisted of a few pieces, and radical ideas were not involved. Defects in design must be expected. Failures are expected but designs will be perfected through these failures.

That something has been accomplished in the twenty-three months since the ap-



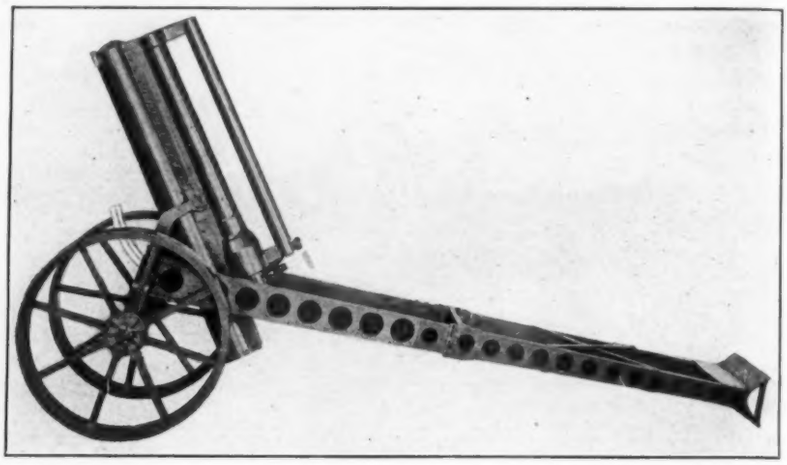
16-inch Barbette Carriage, Model of 1919



14-inch Railway Mount, Model of 1920

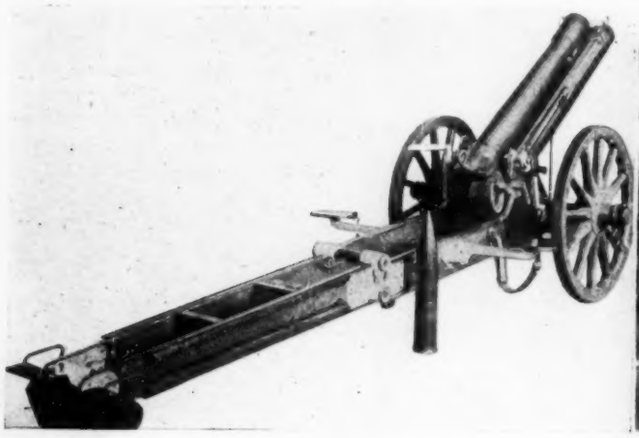
proval of the Westervelt Board report will be apparent from the following statement concerning pieces with characteristics conforming to the specifications of that Board:

There are at the Proving Ground for test an infantry howitzer and a 75 mm. pack howitzer, 75 mm. field guns and 105 mm. field howitzers, and a 12-inch howitzer on railway mount. Two types of motor mounts for 75 and 105 mm. materiel are under preliminary road tests and will be ready for the Proving Ground shortly. Pilots of other calibers will be ready for Proving Ground tests in the near future. A 16-inch barbette carriage has been given a shop test at Watertown Arsenal and manufacture of other railway and seacoast units is well advanced.



2.24-inch Infantry Howitzer, Model of 1920

At the Third Annual Meeting of the Army Ordnance Association to be held at the Aberdeen Proving Ground on Friday, October 7, 1921, it is expected that all of this new ordnance materiel will be proof-fired and maneuvered in public for the first time.



75-mm. Pack Howitzer, Model of 1920

4.7-inch Gun on Anti-aircraft Mount, M. 1920-E; right side, 30° elevation

[Col. Glen F. Jenks, who is a graduate of Hamilton College, New York, was commissioned in the Artillery Corps July 16, 1901, and detailed in the Ordnance Department July 22, 1903, where he has since served almost continuously. His early Ordnance experience was at the Proving Ground and at the Artillery arsenals. He later served four years at Frankford Arsenal in charge of the manufacture and design of fire control instruments, after which he served one year on the Coast Artillery Board at Fort Monroe.

At the outbreak of the war he was stationed in the Philippines, whence he was ordered direct to France. He reported to the Chief Ordnance Officer, A. E. F., France, early in November, 1917, and was assigned as Chief of the Heavy Artillery Division of the Office of the Chief Ordnance Officer, A. E. F. He was promoted to the grade of Lieutenant Colonel November 20, 1917, and to the grade of Colonel January 16, 1918. He held this assignment until ordered to the First Army, A. E. F., as Chief Ordnance Inspector of Artillery, September 13, 1918, which duty he held until after the Armistice when he was returned to the office of the Chief Ordnance Officer as Chief of the Engineering Division which post he held until cable orders were received for his return to the United States

Upon his return to Washington, January 2, 1919, he was assigned as Chief of the Artillery Division, which position he still holds.

In the A. E. F., Col. Jenks was active in securing the adoption of more powerful types of wheel artillery, assisted in the development of motor gun carriages and in co-operation with the French, directed and carried out the design of an improved railway materiel. During the summer of 1918 he was a member of the Artillery Committee of the Inter-Allied Council, and later was instrumental in obtaining the adoption of a common inter-allied program of railway artillery. While with the First Army, he reorganized the inspection and maintenance of artillery materiel service, operated it successfully during the Argonne-Meuse battle and assisted in reorganizing the artillery supply service of the field armies.

He was decorated by the French as an "Officier" of the Legion of Honor and was cited by General Pershing for exceptionally meritorious and conspicuous service as Ordnance Inspector of Artillery.

Since his return he has been in charge of the development of artillery materiel under the Westervelt Board program and under Board of Review projects.—ED.]

Absorption of Moisture by Colloided Smokeless Powder

By

TENNEY L. DAVIS

Member A. O. A.

[Dr. Davis was during the war a First Lieutenant in the Ordnance Department. He is at present Assistant Professor of Organic Chemistry at the Massachusetts Institute of Technology, and is engaged in research for the Ordnance Department looking toward the improvement of powders and explosives.—ED.]

OF the two principal types of military smokeless powder each has its own particular advantages. "Double base" powders which are made from nitrocellulose and nitroglycerine show little or no tendency to take up moisture from a damp atmosphere, particularly so if they are made by a process of manufacture which involves the use of no solvent, and require no particular precautions when fired at the Proving Ground. They probably have shorter life in storage than "straight nitrocellulose" powders which contain no nitroglycerine, and they are quicker and hotter, and produce heavier erosions in the barrel of the gun. Straight nitrocellulose powders tend to absorb moisture from a damp atmosphere and to deteriorate in their ballistic qualities, but the difficulty may be obviated by the use of suitable containers, and is compensated for by their greater stability and by the fact that they are cooler than nitroglycerine powders, produce less erosions, and give a materially longer life to the gun.

The pyrocellulose multi-perforated short grain which is standard in the Unted States has the advantages of its coolness in the gun and of its stability, for it is cooler and more stable even than other straight nitrocellulose powders which are manufactured partly from soluble and partly from insoluble nitrocotton. The form of the grain makes the powder easy to blend and to manufacture in large lots which are ballistically uniform, but this advantage, of course, can also be possessed by suitably shaped nitroglycerine powders. Its ballistic uniformity and coolness make it desirable for artillery uses, and its sensitiveness to moisture offers no serious objection for peace-time uses, artillery practice, and so on, under conditions where containers can be handled easily enough. But, for the hard usage and adverse weather conditions of the front, carefully made and rather expensive containers were necessary. Occasionally a container was torn in transit and the powder could not be used, or, again, when a container filled with base charge and increments was opened for zone firing on a rainy day, powder which was not used immediately had to be discarded because it could now not be relied upon to fulfil in barrage fire the calculated expectations of the artillerymen. But the matter of satisfactory containers, on the whole, was very well worked out.

The Ordnance Department has hoped, however, with whatever expectation of success it has dared to assume, that it may ultimately be possible to produce a powder which shall not be sensitive to moisture and which can be shipped in containers which are not air-tight. A powder possessing all of the advantages of our present powder and at the same time entirely indifferent to moisture would be a very desirable powder. If we could add that it should be as stable and as permanent as black powder, the result would be well nigh ideal, but this last is talk of something which is not likely to be attained in the very immediate future.

Nitrocellulose is itself hygroscopic, but its tendency to take up moisture is materially modified by other substances with which it is incorporated. Colloided, in the absence of solvent, with non-hygroscopic nitroglycerine, it yields a product which shows practically no tendency to take up moisture from a damp atmosphere. Colloided with alcohol and ether, as is done in the manufacture of straight nitrocellulose powder, it yields a product which takes up moisture both because of the hygroscopicity of the nitrocellulose itself and because of the marked hygroscopicity of the alcohol and ether. Our present service powder is therefore hygroscopic for two reasons, one depending upon the material of the powder, the other depending upon the solvent which is used in its manufacture.

In the old air-dried powders the entire powder-grain contains residual alcohol and ether, and the tendency to take up moisture is greatest. In the water-dried powders of the present, the interior of the powder grain contains alcohol and ether, but the alcohol and ether of the surface layer have been largely removed or replaced with water; the hygroscopicity of the surface layer is reduced and the interior of the grain is prevented in a measure from attracting to itself the moisture which it would otherwise attract. In certain coated and "progressive burning" powders the surface layer of the powder grain is made up of material of greatly reduced hygroscopicity and the interior is rendered inaccessible to atmospheric influences.

The following table shows the effect of absorbed moisture on the ballistic properties of standard pyrocellulose powder. A sample of water-dried powder was exposed to an atmosphere practically saturated with water vapor. Portions of the material were removed each day and fired in the gun and analysed for total volatile matter and for volatile matter driven off by an hour's heating at 100° ("external moisture"). The amount of total volatile matter increased regularly during the period of exposure as did also the amount of volatile matter resident at or near the surface of the powder grain which could be driven off by heating. The amount of "residual solvent" or volatile matter in the interior of the powder grain was not materially altered during the duration of the experiment.

Period of Exposure (hrs.)	0	24	48	72	96
Total Volatiles, per cent	3.26	3.55	3.71	3.84	3.93
External Moisture, per cent	1.02	1.15	1.40	1.47	1.57
Residual Solvent, per cent	2.24	2.40	2.31	2.37	2.35
Velocity	1706.6	1699.0	1685.4	1680.4	1669.0
Pressure	31100	31236	30671	29636	28935

During the war the Engineering and Inspection Divisions of the Ordnance Department became interested in the matter of the absorption of moisture by colloided smokeless powder, and investigations along this line have since been continued as a part of the program of research contemplated by contracts between the Ordnance Department and various universities. This is one of the subjects which are being studied at the Massachusetts Institute of Technology. We are trying first to gain some insight into the manner in which the absorption of moisture takes place. If the mechanism of the process is understood, efforts to modify or prevent it are more likely to be successful.

Among the tests which the Inspection Division makes on all lots of powder are the determinations of total volatiles and of external moisture. The difference between the total amount of volatile matter in the powder and the amount of volatile matter which is driven out by drying is reported as "residual solvent," and has been supposed to represent the amount of volatile matter which is retained more or less permanently in the interior of the powder grain. The determination of external moisture is an important one for the reason that it has been found to be desirable to regulate its amount according to the caliber of the powder —the larger the powder grain, the larger, within limits, the amount of permissible external moisture. If the specified limits of external moisture are exceeded, then the powder is of inferior quality ballistically and a portion of its weight is made up of inactive and non-combustible water.

Various nations which use straight nitrocellulose powder have been accustomed to use different methods for the determination of its external moisture. Before the war, for example, in Russia external moisture was determined by heating the sample at 100° for six hours, in France by heating at 60° for four hours, and in the United States by heating at 60° in a vacuum for six hours. During the war it became important to know what method, if any, was accurate for the determination of external moisture. What method, if any, would show the residual solvent to be the same in fresh powder and in the same powder after it had been exposed to moisture? The Inspection Division undertook experiments to find the answer to this question. Samples of powder were taken and residual solvent was determined by a variety of methods; the samples were exposed two weeks to an atmosphere practically saturated with water vapor, and residual solvent was again determined as before. None of the methods was found to be accurate for the determination of true residual solvent, but, more surprising still, it was found in every case that the amount of residual solvent was less after the powder had been exposed to the moist atmosphere than it was before it had been exposed. Yet the powder took up large quantities of moisture during the exposure. Only one inference is possible—exposure of powder grains to a moist atmosphere renders the volatile matter of the interior of the grains more accessible to desiccating influences.

It is well known that water precipitates nitrocellulose from solution in ether-alcohol. The effect occurs even if the solution is so concentrated that it is a stiff jelly; for a grain of new powder, if it has not been treated sufficiently long in the "solvent recovery" chamber and still contains more than seven or seven and a half per cent of solvent, is made "milky" by the water-drying treatment, the water causing the nitrocellulose to precipitate, filling the powder grain with cracks, and depriving it of its amber-like appearance. We therefore took the hypothesis that the absorption of moisture by colloided smokeless powder is accompanied by the production of microscopic cracks or pores in the surface of the powder grain and that it is these cracks which give readier access to the interior of the grain and cause it, if dried after the exposure to moisture, to lose more volatile matter than it could have lost before being exposed.

Verification of this hypothesis was found in the conduct of colloided powder toward alcohol. The powder takes up alcohol from an atmosphere saturated with alcohol vapor. But alcohol is miscible with the ether-alcohol nitrocellulose colloid and its absorption is not accompanied by precipitation or the production of cracks or pores. Residual solvent in every case was found to be greater after the powder had been exposed to alcohol vapor than it had been before such exposure as would be expected in accordance with our hypothesis. The following table shows data for typical samples of powder, before and after exposure of two weeks to atmospheres saturated respectively with water and with alcohol.

Method of Determining External Moisture	*Exposure to Water. Residual Solvent.*			*Exposure to Alcohol. Residual solvent.*		
	Before	*After*	*Difference*	*Before*	*After*	*Difference*
1 hour at 100° in open oven	3.12	2.82	— 0.30	2.41	4.57	+ 2.16
6 hours at 100° in open oven	2.81	2.36	— 0.45	2.22	3.92	+ 1.70
6 hours at 55° in vacuum	2.91	2.54	— 0.37	2.27	4.10	+ 1.83
55° to constant weight in open oven	3.00	2.72	— 0.28	2.58	4.25	+ 1.67
Over sulphuric acid to constant weight	2.95	2.39	— 0.56	2.32	4.10	+ 1.78

Powder which has been exposed to moisture loses on desiccation more volatile matter than it took up during the exposure. If exposed to moisture a second time, after the desiccation, it again takes up moisture, but now, not in sufficient quantity to restore all that was lost during the desiccation. If now again desiccated, it again loses more volatile matter than it had taken up. And so on. Repeated exposure to moist atmosphere and subsequent desiccation renders the powder grain more and more porous—to such an extent that practically all of its volatile matter may be driven out readily by simple heating.

The graph, Fig. 1, shows the variation in the weight of typical samples of two kinds of powder when repeatedly exposed to moisture and dried out. The samples were allowed to stand at room temperature in an atmosphere practically saturated with water vapor, and were weighed every day until constancy of weight had been attained. They were then dried by a six hours heating at 100° in an open oven. They lost more volatile matter than they had taken up, and their weight after drying was considerably less than their original weight. After another exposure to moisture and another drying, it was found that the samples had again lost more volatile matter than they had taken up—but not very much more—and the weight after the second drying was only slightly less than the weight after the first. After the third drying the variation was still less. After the fourth and fifth dryings the weights were practically the same.

When a sample of fresh powder is exposed to moisture, the nitrocellulose, being hygroscopic takes up some moisture on its own account; but the alcohol and ether which are present in the powder grain attract other moisture which produces precipitation and fills the surface of the grain with minute cracks. When the sample is now heated, the water held by capillary action in these cracks, is driven off; the cracks give access to the interior of the grain and

a portion of the residual solvent and hygroscopic moisture, formerly inaccessible in the interior of the grain, is driven off. By a second exposure to moisture new cracks are formed, and on a second heating more of the residual alcohol and ether are driven off, until finally, after repetition of the process, the sample has lost all of its alcohol and ether and the powder grains have become "perfectly porous." Whatever moisture the powder now takes up from a moist atmosphere is due entirely to the hygroscopicity of the material of which the powder is made. Since all alcohol and ether has been driven off, these can have no effect in attracting moisture. When such a sample of powder is heated it loses all the moisture it has and becomes anhydrous. When again exposed to moisture it takes up precisely the same amount as that which had been driven off by the drying.

The tendency of fresh powder to take up moisture is a matter to be remedied. To deal with it adequately it is necessary to know the hygroscopicity, not merely of the fresh powder, but of the alcohol-and-ether-free anhydrous material of the colloid. Our experiments have given us a means of determining this value. By repeated exposure to moisture and drying the powder at last comes to the condition where the gain on repeated exposures and the loss on repeated desiccations is the same. This amount is the amount of moisture which will be taken up by the anhydrous material of the colloid and is the lowest hygroscopicity theoretically possible for a powder of the particular

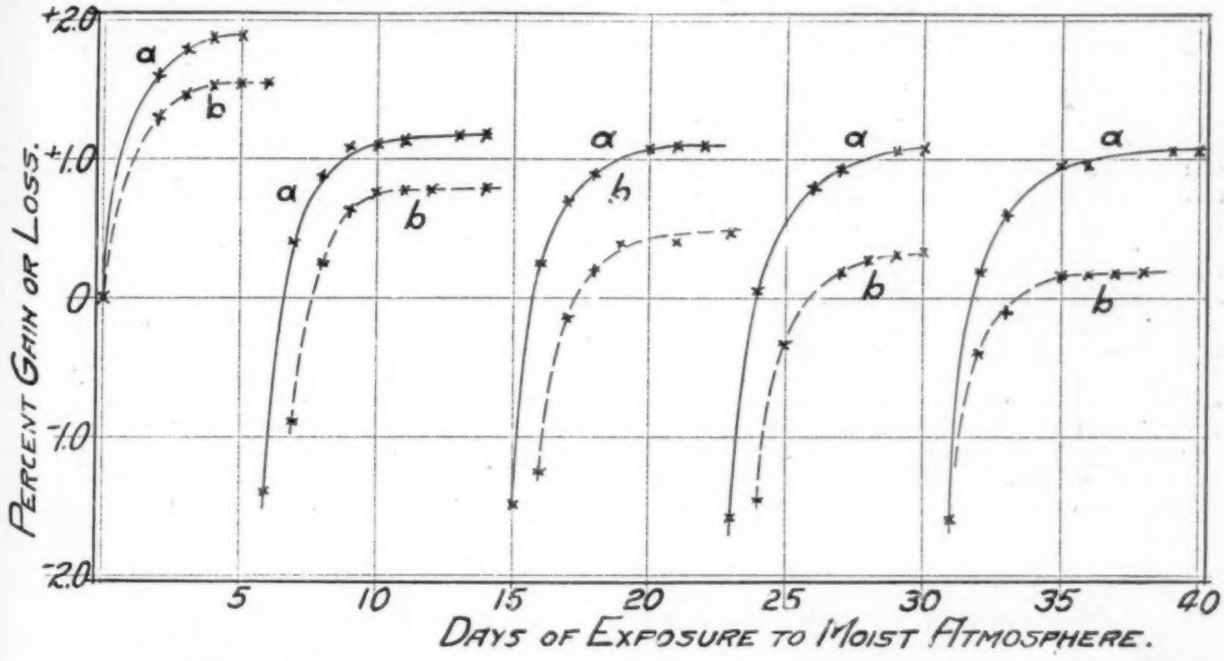


Fig. 1. Effect of repeated exposure to moisture and drying. Percent variation from the original weight of the powder is plotted. (*a*) Standard Pyrocellulose Powder. (*b*) Pyrocellulose Powder containing 10% Crystalline Dinitrotoluene

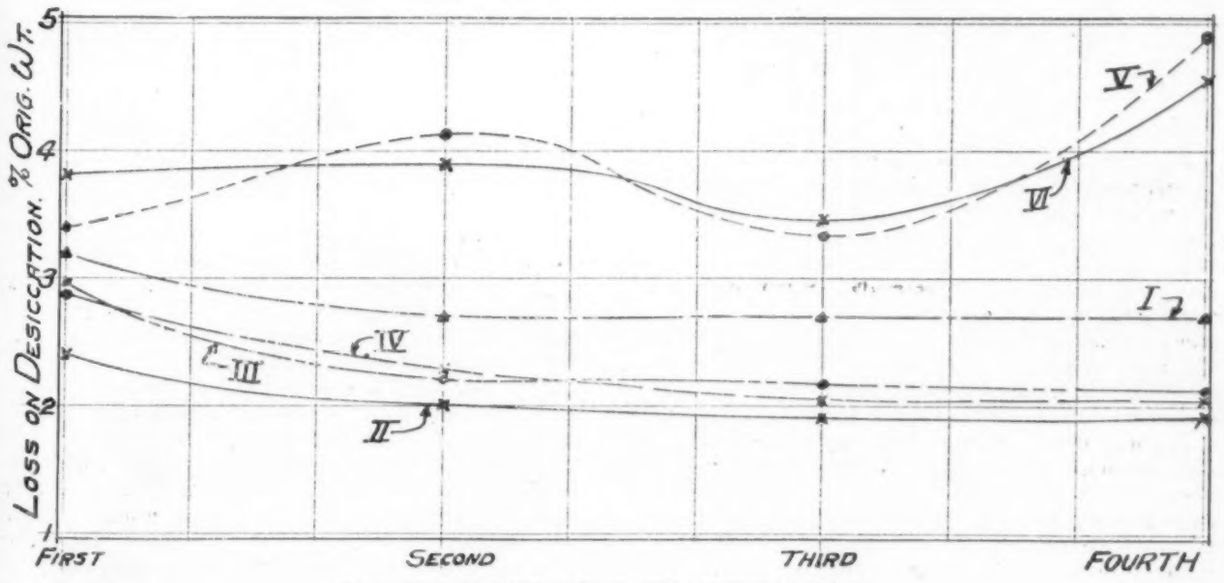


Fig. 2. Loss on desiccation after successive exposures to moisture

composition in question. In the following table the figures represent the per cent of moisture which will be taken up by perfectly dry colloids of the compositions which are indicated.

The Hygroscopicity of Colloids.

I.	Pyrocellulose	2.75
II.	Pyrocellulose with 10 per cent crystalline DNT	1.93
III.	Pyrocellulose with 10 per cent crystalline DNX	2.09
IV.	Pyrocellulose with 10 per cent DNX oil	1.99

The curves, Fig. 2, which show the loss of weight by six hours heating at 100° after successive exposures to moisture, are interesting for a number of reasons. Curves I, II, III and IV give data for new samples of water-dried powder, and show the basis from which the above table of the hygroscopicity of colloids was calculated. The curves flatten out and show no tendency to rise again. This means that the powder had not begun to decompose during the course of our experiments, and justifies our inference that the powder grains, repeatedly exposed to moisture, had at last become "perfectly porous."

Curves V and VI are for samples of the oldest air-dried powder which it was possible to obtain, V being for a powder seventeen years old and containing no stabilizer, and VI for 10-year old powder stabilized with diphenylamine. They show an interesting difference between old powder and new, and between air-dried powder and that which had been manufactured by the newer water-drying process. The curves for fresh samples of water-dried powder drop at once; those for the old samples of air-dried powder rise at first, then drop, and finally rise again. The primary rise of the curve indicates that the surface of the grain of the old powder is filled with alcohol and ether and is different in its physical nature from the surface of a grain of water-dried powder. The later dropping of the curve is evidence of increasing porosity, while the final rise indicates that considerable decomposition has set in and has overridden the other factors which determine the weight of the sample.

Conclusions

We have discovered what happens when colloided smokeless powder takes up moisture from a damp atmosphere and have elucidated the causes of such absorption. We have found a means of determining the hygroscopicity of the solvent-free material of the colloid and for comparing the hygroscopicity of various kinds of powder. Experiments will be continued with powders of various compositions, with powders containing various colloiding agents incorporated throughout their mass or applied as surface coatings, and with powders which have been dried by different processes or subjected to different surface treatments—in the hope that it may ultimately be possible to prepare a powder which shall have, in addition to the advantages of our present powder, the advantage of being entirely indifferent to moisture.

Scientific Data for Ordnance Engineering

By

W. H. TSCHAPPAT
Member A.O.A.

While there are some special features in the manufacture of ordnance, not usually encountered in commercial work, yet, on the whole, manufacturing methods need not differ in principle from those of commercial practice. The difficulties in the procurement of the necessary machinery and equipment having been overcome, the manufacturing skill and facilities of the country can always be partially diverted, in time of necessity, to the manufacture of ordnance and other munitions. This cannot be done, however, in the design of ordnance; and it may be assumed that new designs will always be required in time of emergency.

In a long period of peace, following a great war, knowledge concerning the design of ordnance gradually dwindles down in point of numbers having it, until all this special knowledge is held by the government officers and employees placed in charge of the work and such manufacturers as can keep their plants employed with the peace-time orders they get from the Government.

It is, of course, very desirable that designs of all types of ordnance be worked out, agreed to and adopted in peace time and that these designs be improved from time to time and kept up to date, so that they may be put into production when necessary; yet in any great war a tremendous amount of new design work will have to be undertaken. For example, in the late war, improvements in aeroplanes and their equipment, including drop bombs, improvements in projectiles, the development of the tank, gas warfare, etc., each called for a large amount of design and development work which had to be done while the war was under way.

Now, much of the engineering work required to produce a design of almost any kind of ordnance is just plain machine design. The knowledge required does not differ from that required to produce the design of a lathe or an automobile. Evidently there ought to be no trouble in obtaining personnel to produce work of this kind.

In almost every completed piece of ordnance, however, there are points which require special knowledge in the designer. One of the best illustrations is the design of a fuze. The requirements may be simply that the fuze must be safe against premature action in the gun and that it must act promptly when the projectile strikes the ground. The uninformed designer would probably undertake this problem with entire confidence, as the requirements seem simple; but unless he has followed practice rather than theory, he is probably due for a rude awakening on the first proving ground test. Unexpected weakness will develop in the mechanism of the fuze when subjected to the tremendous inertia forces in the gun. The fuze may not "arm" or it may arm and again disarm before the firing pin pierces the primer. All these may cause failure to function or may cause premature ignition of the fuze and explosion of the projectile in the gun.

In the recuperators of gun carriages we have another

example of a machine which requires non-commercial engineering to produce a successful design. The whole problem of the control of the recoil of guns—produced as it is by the quickly, yet not instantaneously, applied pressure of the powder gas in the gun—is one which requires special engineering knowledge. The same can be said of the designs of guns whether the method of construction is "built-up," wire wound, or the latest one based on "auto-frettage." There are many other articles, the design of which requires special engineering knowledge.

In all these special problems not only is there a lack of engineering knowledge extant, but engineering data are scarce and not available in a convenient form. Usually, also, there is some doubt as to the reliability and accuracy of the data on hand. In short, these are problems upon which a certain amount of research and investigative work could be carried on profitably. This work might be of two kinds:

(*a*) Such trials or tests of a pilot or model as will furnish the facts necessary for correct engineering in producing this particular finished design.

(*b*) Such investigation of the fundamental laws governing the working of the pilot or model as will furnish a basis for the design of any machine subject to these laws.

The work under (a) would usually be done in the shops where the article is being manufactured or at the proving ground and under the direction or observation of the designer or engineer responsible for the design. It presupposes at least a partial knowledge of the laws referred to in (b) for the particular article considered. The test might include several models or pilots differing slightly from each other, and tested simultaneously to try special features comparatively; or a number of models might be made and tested successively, each embodying improvements suggested by the test of the preceding one. The proceeding is altogether similar to that used by commercial firms in getting out new models of machinery, automobiles for example. The work under (a) is primarily engineering work and is to be considered as necessary in developing a new design.

The work under (b) is of quite a different nature. Under this heading comes the investigation of such fundamental laws as that of air resistance on projectiles, as affecting their form and design; the law of flow of metal when stressed beyond the elastic limit as affecting the design of guns built by the auto-frettage system; the blasts of guns and the possibility of utilizing its energy in the checking of recoil. In addition, investigation of improvements in propellants and high explosives comes under this heading. All these investigations can preferably be carried on apart from the engineering work proper, just as the engineering work may well be carried on apart from that of manufacture. The work under (b) is best carried on at a Proving Ground or Arsenal in a modern laboratory fully equipped for physical, chemical and metallurgical research. The universities of the country are well equipped with laboratories of all three kinds and have experts qualified to handle these problems. Though all of them are busy on investigative programs of their own, many are ready to undertake work on some of these problems. At least two government bureaus, the Bureau of Standards and the Bureau of Mines, are equipped to undertake many of these problems. Naturally, however, the universities would prefer in time of peace to work upon problems having commercial application or greater scientific interest. The students whom they are training would, of course, be more interested in such problems than in the special Ordnance problems with which they do not expect to deal.

Many ordnance research problems have commercial applications. For example, nearly all of our metallurgical problems have their counterpart in commercial work. Most of the problems concerning tractor engines and their accessories also apply to engines for commercial trucks. But in all these problems, in which it is felt that research and investigative work on a laboratory scale would lead to improvements more rapidly than can be attained by ordinary engineering methods, or that would lead to new designs or products of superior merit, it is a function of the Ordnance Department to make certain that the necessary research is undertaken at the place at which it can be carried out with the greatest economy combined with the necessary thoroughness and completeness. In carrying on such scientific work, it is to be understood that the purpose of the Ordnance Department is primarily to obtain the necessary data for the solution of some particular problem; and when sufficient data are obtained the investigation would ordinarily stop, though an investigator interested in the problem from the scientific point of view alone might want to carry it further.

Whether work of this class is done by universities, by government bureaus or by ordnance establishments, a certain number of Ordnance officers or employees should have the scientific training to permit them to keep in touch with work of a similar nature in progress at universities and commercial plants, and to assist in applying the results of such work to Ordnance engineering.

Engineering problems are now presented to the Ordnance Department for solution substantially in the form of lists of requirements to be met by the articles under consideration. It is a function of the Ordnance Department to meet the requirements, going one better if possible, or to show that they cannot be met. Depending upon the nature and uses of the article, the requirements may be in great detail or on the other hand they may be very general in their nature.

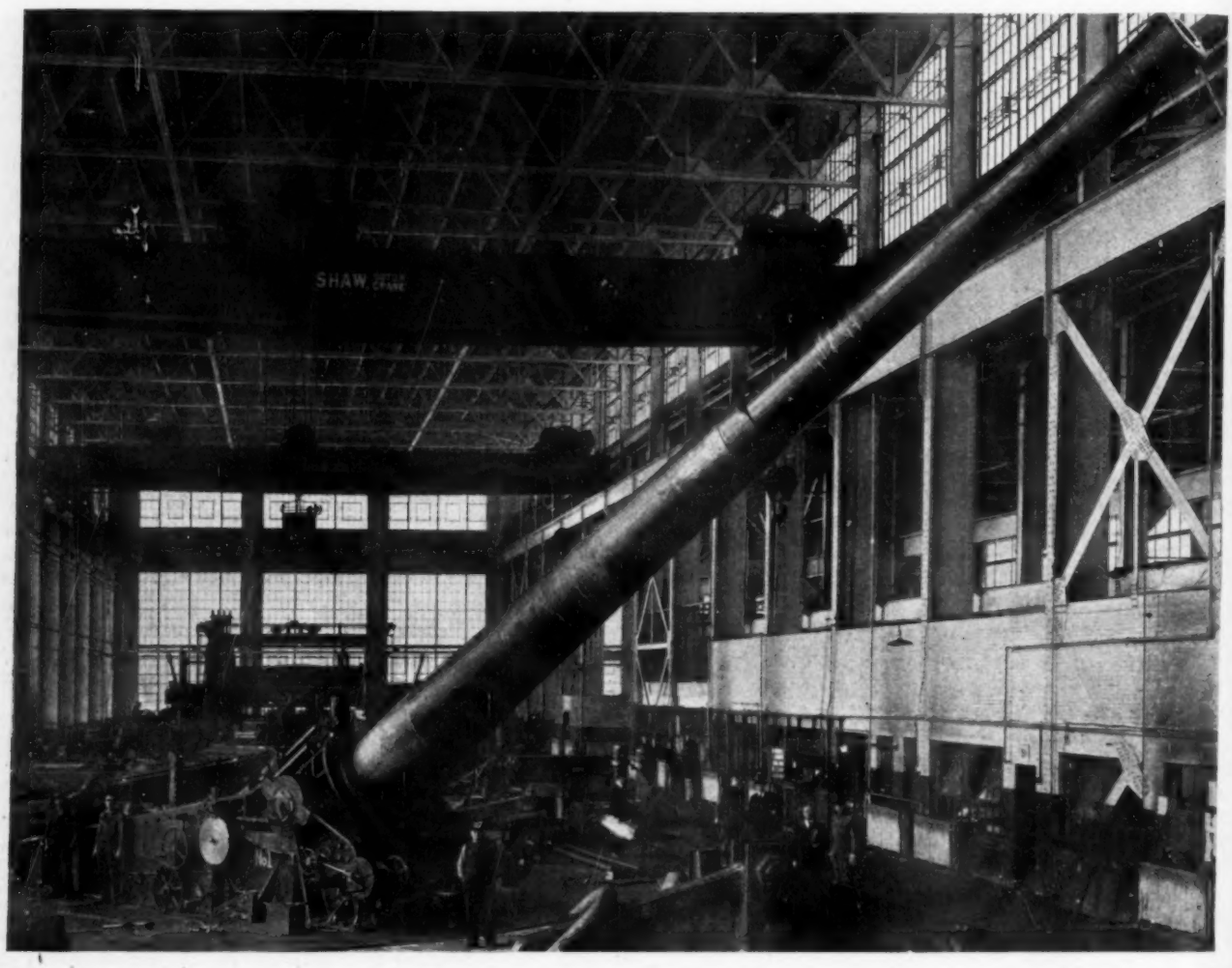
No organization outside of the War Department, although thoroughly well qualified technically, could be in such close touch with the trend of thought in the Army as to give the proper degree of weight and importance to the various features of the requirements and to the various engineering and technical questions which come up in the development of the design. On the other hand, unless there are Ordnance officers or employees technically trained and in touch with scientific progress, certain of these questions may either fail to receive the necessary investigation, be investigated along too restricted lines, or be over-investigated.

The scientifically trained ordnance officer or employee will tend to keep a balance between the tendency of the ordnance engineer or the manufacturer to limit investigative work to that immediately necessary to determine the suitability of a given design and that of the scientist whose natural desire may be to investigate those points which have the greatest scientific interest but which may not be of the most immediate importance. The present approved system of education of officers includes special courses at universities along scientific lines. The effect upon products supplied to the Army by the Ordnance Department should make itself felt in a few years.

The New 16-Inch 50-Caliber Gun

Mounted on Barbette Carriage Outranges Any Gun

Either at Present Mounted or Contemplated to be Mounted on Any Battleship in the World



The Huge Piece of Ordnance shown above will be Proof-Fired during

The Third Annual Meeting of the Army Ordnance Association

Aberdeen Proving Ground, Maryland

Friday, October 7, 1921

16-Inch 50-Caliber Gun and Barbette Carriage

By

G. M. BARNES

Member A. O. A.

ARTILLERY authorities have always maintained that land fortifications are superior to battleships. This contention was strengthened during the World War by the results of the combined British and French attacks upon the Turkish coast defenses at the Dardenelles and upon the German defenses along the Belgian coast. The strong resistance made by the old Turkish forts at the Dardenelles furnishes an excellent example of the power of the land fortifications over ships at sea. The land batteries, with the exception of a few at the entrance of the Narrows, although under the terrific fire of the combined fleets, were not silenced. At the entrance, the old guns were many times out-ranged, but the ships had plenty of sea in which to maneuver, and could bring their heavy guns to bear. The Turkish short range guns, in this case could not reply. When, however, the allied ships attempted to enter the Narrows, they came within range of the short batteries and entered an area in which fixed and floating mines had been laid. The allied losses then became so heavy that it was necessary for them to retire and abandon the attack.

The German defenses, hastily erected along the Belgian coast, were constantly shelled by the heavy guns of the allied monitors. The positions of the German guns were accurately known, as allied aviators had photographed them. These aviators dropped a large number of bombs upon the German batteries, but there is no evidence that any of the German guns were ever hit or damaged by shell fire from ships or by drop bombs from aeroplanes.

In brief, the World War again conclusively demonstrated that battleships can not hope to successfully attack land fortifications if the land guns range with those on the ships.

A few years ago, the guns on the battleships of all countries could not be elevated more than fifteen to twenty degrees. The new ships built since the war will have an elevation of forty degrees and a correspondingly long range. This makes it necessary that the carriages of all new seacoast weapons provide a high angle of elevation. A new long-range seacoast weapon has been recently completed by the Ordnance Department at the Watertown Arsenal, Watertown, Mass., and shipped to Aberdeen Proving Ground for test. This unit has been designed to incorporate the lessons taught by the World War, and will *outrange any guns now mounted or contemplated for battleships.*

A brief description of this new unit will be given in order that some idea may be had of its great size and of the manufacturing problems which enter into the production of this class of Ordnance. At the outset, it should be understood that weapons of this caliber cannot be built in less than three to four years' time and guns of this size which are available for use during a war are those for which funds are appropriated by Congress and which are built in time of peace.

The 16-inch Gun and Barbette Carriage are shown in Fig. 1, which gives a cross-sectional view of the carriage and emplacement. This gun of wire-wound construction is approximately 70 feet length overall, and with its recoil band weighs about 200 tons. It is equipped with a drop breech block of the Smith-Asbury type which can be operated by compressed air.

The charge for the gun consists of 850 pounds of smokeless powder which gives a maximum interior pressure of 38,000 pounds per square inch. An armor piercing projectile weighing 2,340 pounds is used for attacking the armor of ships and gives a penetration of 14 inches or more of armor at all ranges. Computation shows that a range of 50,000 yards may be expected.

Although the carriage is simple in design, nothing essential to the rapid and accurate maneuvering of the gun has been omitted. The principal parts of the carriage are the base ring, racer, side frames, cradle mechanism, loading arrangement, electrical equipment, elevating and traversing mechanism.

The base ring, as the name would indicate, is the base or foundation for the carriage. It is made up of four steel castings bolted together to form a large steel ring (32 feet outside diameter) weighing approximately fifty tons. The upper surface of this ring is accurately machined to form the lower roller path. The gun and the remainder of the carriage rest and can be traversed upon this casting. It is provided with holes to receive the foundation bolts which anchor it to the concrete block and serve to transmit the firing stresses into the foundation. When the carriage is erected at the fortification, it is necessary to accurately level it in two directions, so that the cradle trunnions will remain horizontal in all positions of traverse. This is accomplished by leveling screws which extend through the base ring and bear against steel plates placed on the concrete. After the concrete has been poured around and under the base ring, these leveling screws are slackened off and the nuts on foundation bolts tightened.

There are only two or three boring mills (see Fig. 3) in the United States of sufficient size to machine a steel ring of this weight and diameter. As an example of the unexpected difficulties constantly encountered in this class of work the following is cited. In making the finishing cut on the roller path, when machining the base ring, it was found that the tool lost its edge before a cut could be completed, due to the great circumference of the piece (over 100 feet). It was, therefore, impossible to get the required finish since a new tool could not be substituted during the operation. The tool head of the machine was

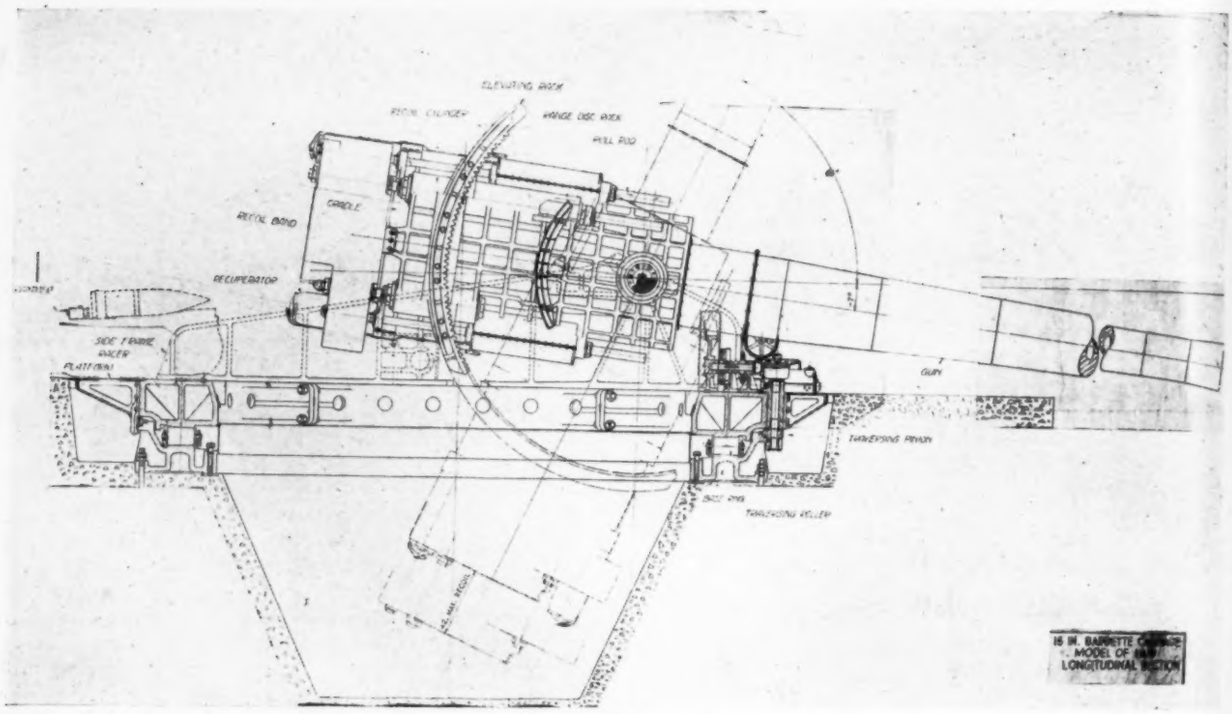


Fig. 1

modified so that a grinding wheel could be substituted for the machine tool and the roller path successfully completed by grinding.

The racer, which is also made up of four castings and quite similar to the base ring, is placed over the base ring but separated from it by steel rollers. The lower surface of the racer is machined to form the upper roller path. The steel rollers, which are conical, are held in alignment by a cast steel distance ring. (See Fig. 2.) The racer is kept concentric with the base ring when the gun is traversed or fired, by means of a pintle which projects inside a similar surface on the base ring. A very small radial clearance is provided between these surfaces. See Figs. 1 and 2.

The gun, cradle, side frames and racer rest upon the large roller bearing consisting of the 42 live rollers. A circular rack is bolted to the outside of the base ring while a pinion attached to the racer meshes with this rack and is connected through suitable gearing to the traversing handwheels. (Fig. 1.) An electric motor and hydraulic speed gear permit the carriage to be traversed by power. The outside surface of the base ring is graduated in degrees. By means of the micrometer index which is carried on the racer, the carriage can be laid in direction with an accuracy of one two-hundredth of a degree.

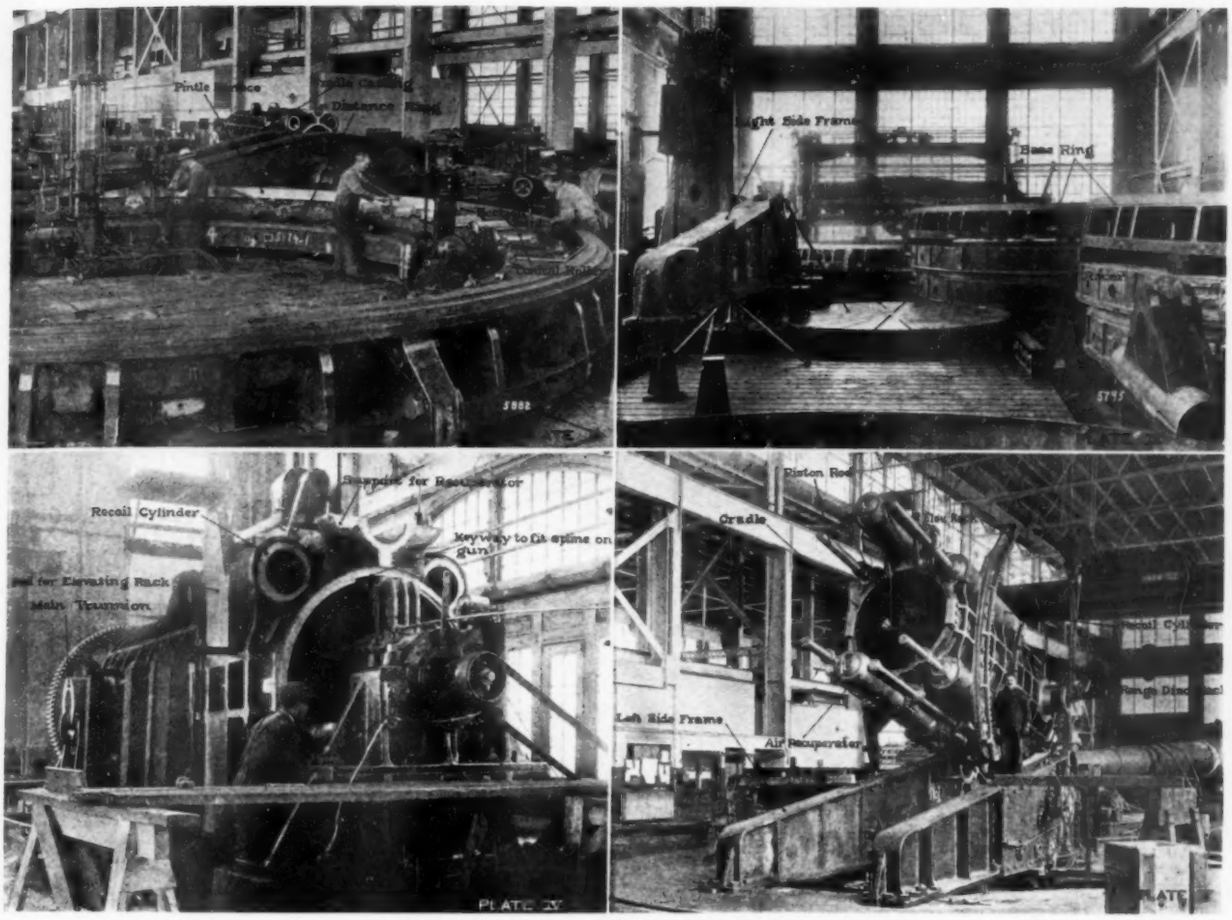
The cast steel side frames (Figs. 3 and 5), which weigh 25 tons each, serve to support the gun and cradle at the proper height above the racer. They are bolted and keyed to the racer and transmit the firing loads through the base ring into the foundation.

The elevation of the gun is controlled by circular racks (Fig. 5) bolted and keyed to the right and left sides of the cradle. Two pinions projecting from the interior surfaces of the right and left side frames mesh with the two racks. These pinions are connected through suitable gearing to the elevating handwheel and also to an electric motor and hydraulic speed gear which permit the gun to be quickly set in elevation by power. By means of the fine control possible with the hydraulic gear, the gun can be quickly laid at any elevation between minus 7 degrees and plus 65 degrees with an accuracy of one minute. Automatic stops are provided so that the gun will come to rest without shock at the limits of elevation and depression when using power. Spring buffers act as final stops at minus 7 degrees and plus 65 degrees.

The cradle forms a sleeve in which the gun recoils when fired. It contains or supports all the mechanism which controls the recoil and counter recoil of the gun, and is connected to the side frames by trunnions which permit the gun to be elevated between limits.

The cradle is an intricate casting weighing about 50 tons in the rough, the inside of which must be very accurately machined to fit the outside contour of the gun. Circular bronze strips are bolted to the inside and form bearings for the gun to slide on. The gun also carries two longitudinal keys which fit into corresponding slots in the cradle. These key-ways form additional bearing surfaces and resist the rotation of the gun produced by the twist of the rifling. The fit between the gun and the cradle must be very accurate and the machine work must be done to such a nicety that the angle of repose of the gun in the cradle will not exceed six degrees. The angle of repose is measured by unscrewing the piston and recuperator pull rods about one-eighth inch and slowly elevating the gun until it just starts to slide out of the cradle.

The gun and cradle, which weigh 550,000 pounds, are so accurately balanced upon the trunnions that one man by hand power can easily set the gun at any desired angle of elevation. To reduce the trunnion friction to a minimum, roller bearings have been introduced at the trunnions. These bearings which carry the dead load of the gun and cradle mechanism, are, however, supported upon elastic cushions which deflect under the firing load, thus preventing the rollers from crushing. This mechanism, Fig. 7, consists principally of a plug, a roller bearing, a crutch, a



Machining and Assembling 16-Inch Barbette Carriage

Upper left: Base Ring and Traversing Rollers

The Base Ring consists of two halves accurately machined to present a conical upper surface—the roller path—upon which the conical rollers move when the Racer and Carriage are traversed for laying in Azimuth.

Upper right: Side Frame, Base Ring and Racer

In the background can be seen the large Vertical Boring Mill at Watertown Arsenal. There are only three machines in the U. S. capable of machining a steel ring 40 ft. in diameter.

Lower left: Machining the Cradle Casting

This is a single steel casting weighing 50 tons in the rough. It contains all the mechanism for controlling the recoil and is one of the most difficult parts of the carriage to construct.

Lower right: The completed cradle is being put in position on the side frame. The large cradle trunnions take the pull of the gun in recoil, and also permit it to be laid at the proper elevation.

lever and Belleville washers. The trunnions are sufficiently hollowed out to permit the roller bearing to be threaded over the plug which takes seat in the trunnions. The dead load of the gun and cradle is lifted off the main trunnion bearing and transferred to the roller bearing by means of the crutch and lever. The lever is supported at one end on a pin and at the other end by Belleville washers which deflect under the firing load, allowing the main trunnion to again come in contact with the main trunnion bearing. As soon as the firing stresses have been relieved, the Belleville washers lift the lever so that the dead load is again carried by the roller bearing. Anyone especially interested in the use of large roller bearings under heavy loads is referred to the report of the test made at Watertown Arsenal given in some detail in *American Machinist* for July 29, 1921, page 200.

The recoil of the gun is controlled by four oil cylinders, symmetrically located and cast integral with the cradle. These cylinders are provided with steel liners which prevent leakage at high pressures. The four piston rods extend to the rear and are fastened to the recoil band which is securely keyed to the gun. The energy of fire is dissipated by throttling oil through grooves cut in the wall of each cylinder, as the piston rods and heads move to the rear with the gun. The cross sectional area of these grooves is calculated so that the piston rod pull will be constant throughout the length of recoil. In this carriage the piston rod pull amounts to 1,250,000 pounds over forty inches of recoil, so that the recoil cylinders dissipate 4,567,000 foot pounds of energy.

In 1916 the Department started the design of a somewhat similar gun and carriage. Spring recuperators were contemplated and it was found that the largest spring which could be made in this country would return the gun only at thirty degrees elevation. To return the gun to battery at sixty-five degrees it was therefore necessary to use an air recuperator system. The high elevation obtained with this gun carriage was therefore only made possible by the use of the hydropneumatic recuperator. This system consists of two air cylinders with pistons each having an effective piston head diameter of 12.25 inches. Compressed air at 1,750 pounds initial pressure acts against the pistons to hold the gun in battery. When the gun is fired and recoils, the air is further compressed and this supplies the necessary energy for returning the gun into the original position for the next shot.

The problem of counter-recoil was even more difficult than the recuperator problem. It will be appreciated that

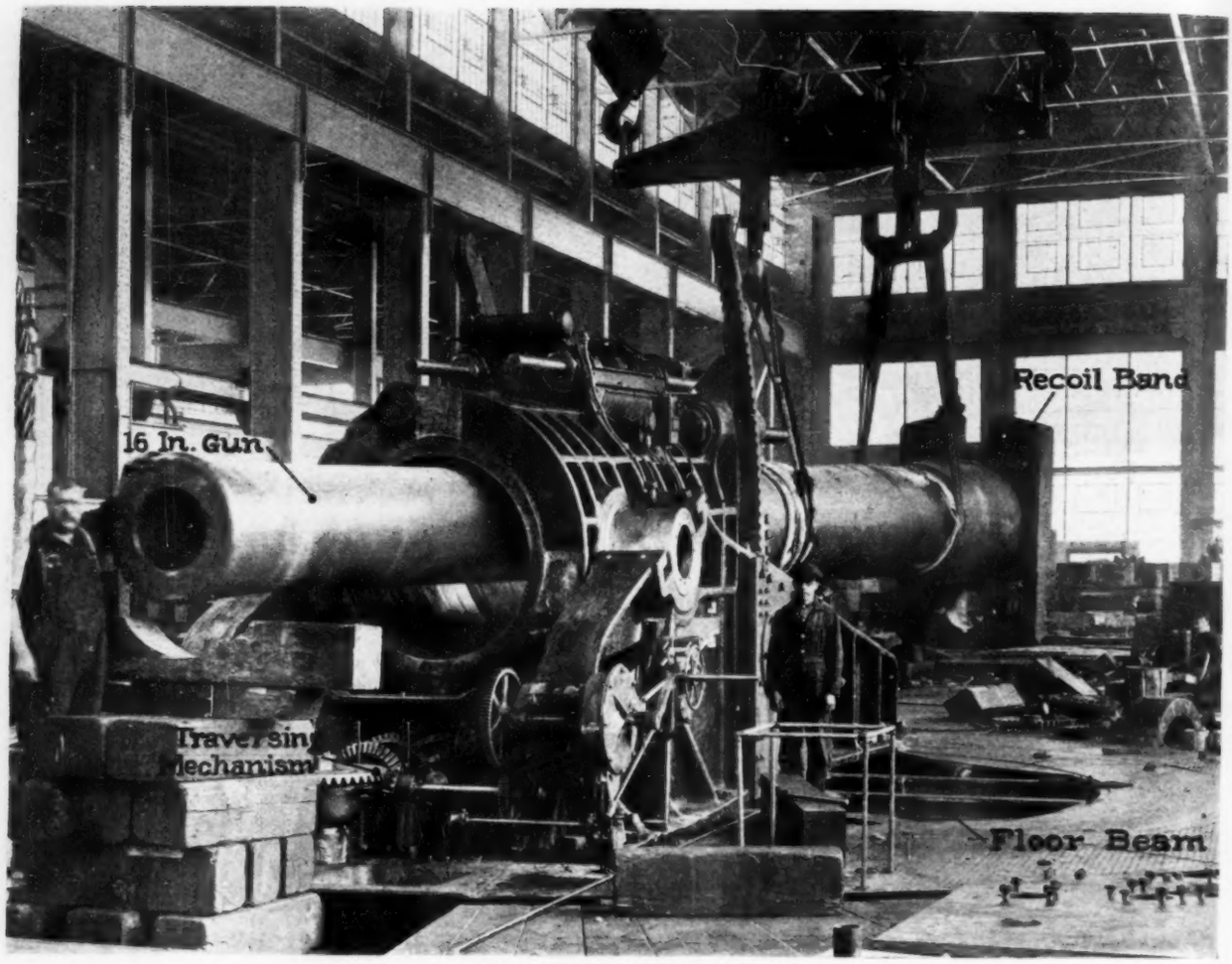


Fig. 6. 16-Inch Barbette Carriage
The gun is being run into position in cradle. The holes in the recoil band receive the piston and recuperator rods which control the action of the gun in recoil and counter recoil

if the recuperator mechanism is made powerful enough to return the gun and recoiling parts, weighing two hundred tons, to battery at sixty-five degrees elevation, there will be a great excess of recuperative power when the gun is at zero degrees or at minus seven degrees depression. An automatic buffer is necessary which will act as a powerful brake at low angles, but will have little or no effect at the higher angles of elevation. It was, therefore, necessary to design a special counter recoil buffer mechanism for this carriage. Shop tests made at Watertown Arsenal indicate that the new system devised is entirely satisfactory.

A cross-sectional view of the recoil and counter-recoil mechanism is shown in Fig. 8. As the gun recoils it carries the recoil band to which the piston rods are attached to the rear or to the left as shown in the illustration. Oil is throttled past the piston head shown at the center of the cylinder, through recoil grooves of varying cross section cut in the walls of the cylinder. The valve in the second piston head at the right opens during recoil and allows the oil to pass freely. On counter recoil this valve closes and the movement of the gun into battery is controlled by a second set of throttling grooves cut in the walls of the cylinder along the path of this piston.

These grooves are much smaller in cross sectional area than the recoil grooves and thus control the movement of the gun on counter recoil. If the gun is at a high angle of elevation, it moves slowly into battery as the force returning it to battery is equal to the effective pull of the recuperator minus the component of the weight of the gun in the same direction minus frictional resistances. In this case the pressure developed in the cylinder during counter recoil is small. If, however, the gun is at a low angle of elevation, the recuperator tends to throw the gun into battery at a high velocity since the component of the weight of the gun is small. Therefore a high pressure is developed in the cylinder which quickly reduces the velocity of the recoiling parts. The system is thus automatic between wide limits of elevation and controls the gun so that it will move slowly and smoothly into battery at all angles of elevation.

As the projectile weighs 2,340 pounds (Fig. 9) and the powder charge 850 pounds, the problem of rapidly loading the gun was a difficult one. To insure a high rate of fire of at least one shot per minute, a power rammer has been located on the racer near the breech of the gun. The projectile and powder are rammed into the gun by this means. The rammer is driven by an electric motor connected through a hydraulic speed gear to insure good control. Powder and projectiles are brought up to the carriage in special cars operating on standard gauge tracks.

In addition to the azimuth circle already described, the carriage is equipped with two telescopic sights for direct fire. A range disc which can be quickly removed and re-

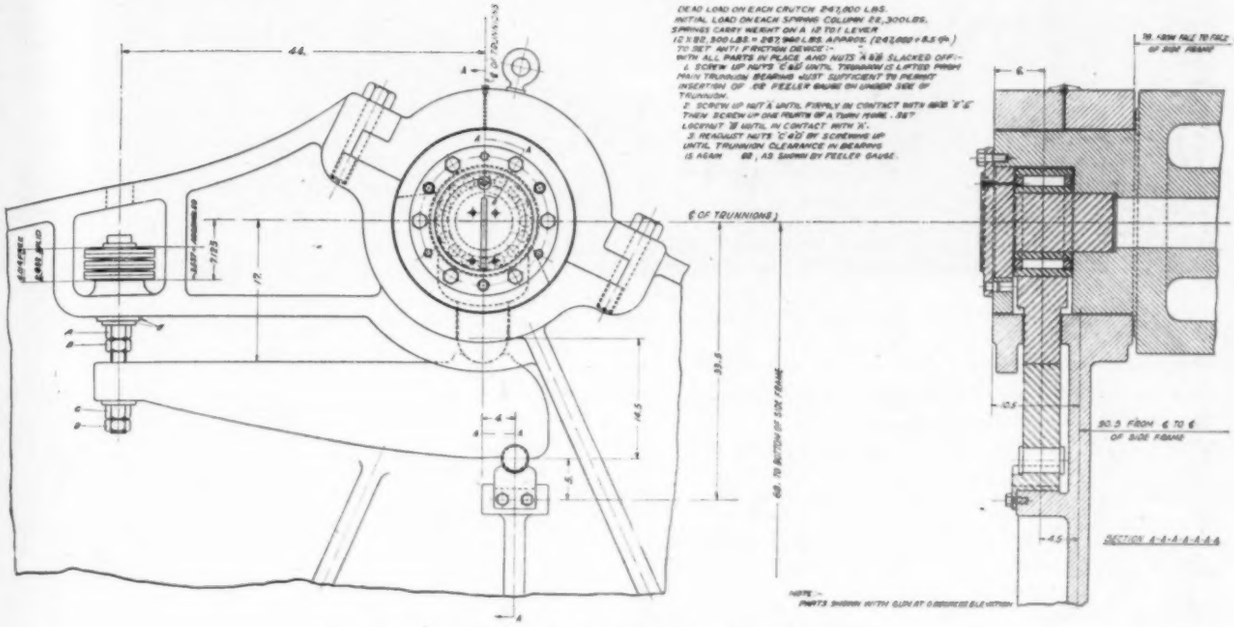


Fig. 7. 16-Inch Barbette Carriage, Model of 1919. Anti-Friction Assembly

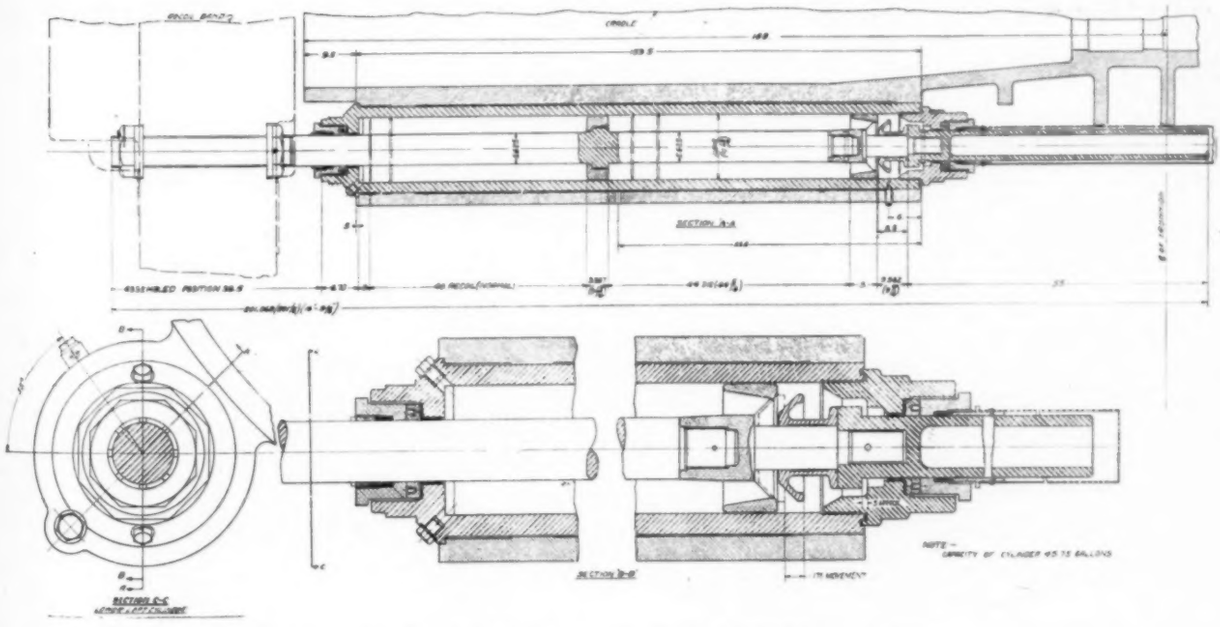


Fig. 8. 16-Inch Barbette Carriage, Model of 1919. Recoil Cylinder Assembly (Long)

Fig. 9. 16-inch Armor-Piercing Projectiles—Weight 2,340 pounds each
These projectiles are capable of defeating 16-inch armor at 20 degrees impact

placed, indicates the elevation of the gun directly in yards of range. Several discs will be provided for each carriage, making zone fire possible. A quadrant reading degrees and minutes is also located at the right trunnion.

Air Compressor Unit

An air compressor driven by an electric motor is located in a compartment attached to the under surface of the racer of the carriage. The compressor furnishes compressed air for the operation of the breech block and for ejecting the gases from the bore of the rifle after firing. As a safety precaution, the operation of opening the block introduces a charge of compressed air in the bore sufficient to remove all gases, thus preventing the hot gases in the bore from blowing to the rear when the block is opened and burning the personnel.

Although the carriage is completely equipped so that all operations can be done by power, the mechanisms permit all operations to be performed by hand power. Electric lights are provided in all motor compartments, at the sights, quadrant, azimuth scale and wherever needed on the carriage in order that it can be efficiently operated at night.

Meeting of Ordnance Section, American Society of Mechanical Engineers

By special invitation of Maj. Gen. C. C. Williams, Chief of Ordnance, about one hundred members of the A. S. M. E. and the Army Ordnance Association visited Rock Island Arsenal on Friday and Saturday, May 27 and 28, following the Spring Meeting of the A. S. M. E. in Chicago, May 23 to 26, inclusive.

The party arrived early on the morning of May 27, and headquarters were established at the Blackhawk Hotel, Davenport, Iowa. The Tri-Cities Section of the A. S. M. E. had arranged for automobiles to call for the visiting engineers at nine o'clock Friday morning, and the party drove directly to the arsenal, proceeding at once to the hydro-electric power plant. After a thorough inspection of the power station, they proceeded to the Proving Ground, where the new experimental 105 mm. howitzer, model 1921, was proof fired, the various details and records in connection with this process being carefully explained to the visitors by Maj. C. A. Waldmann, General Manager of the arsenal. Following the proof firing, the party proceeded to the office of the Commanding Officer, where a large map of the island was exhibited and explained to the visiting engineers, great stress being laid upon the increased facilities at the arsenal made possible by war developments. A tour of inspection then followed, the itinerary covering Shop L, Chemical and Physical Laboratory, Hydraulic Press Department, Tank and Tractor Department, Recuperator Plant, Steel Storage and a representative group of Storehouses, where the visitors were given an opportunity to see the large quantities of guns, caissons, limbers, tanks, tractors and many varieties of smaller Ordnance stores held in reserve at this arsenal.

At 1:30 P. M. the first professional meeting of the Ordnance Section of the A. S. M. E. was held at the Welfare Center of the arsenal, E. S. Carman, President of the A.S.M.E., presiding.

Colonel Ruggles' paper on "Munitions Preparedness" was followed by papers on "Progress in Ordnance Development Since the Armistice." The subject of artillery was covered by Maj. G. F. Jenks, Chief of the Artillery Division. Maj. L. B. Moody, Chief of Tank, Tractor and Trailer Division, presented a most interesting paper on tanks, tractors and trailers, amply illustrated with lantern slides and moving pictures. Maj. W. B. Hardigg covered the subject of artillery ammunition and Maj. L. O. Wright presented a very able discussion on small arms, machine guns and their ammunition. One of the most interesting of the five papers was Maj. W. A. Borden's on aircraft armament, in which he devoted considerable time to the discussion of bombs and bomb racks, both of which are now under manufacture at Rock Island Arsenal.

Friday evening ninety of the engineers gathered at the Blackhawk Hotel, Davenport, Iowa, at a banquet given under the auspices of the several engineering societies in the Tri-Cities. The banquet was presided over by Max Sklovsky, Chief Engineer of Deere & Company, as toastmaster, and the address of welcome was made by Mr. Wm. Butterworth, President of the same organization. Mr. Butterworth's address was very timely and highly appreciative of the value of the technically trained man in almost every department of modern business. Responses were made by President Edwin S. Carman for the A. S. M. E.; President A. E. White for the American Society for Steel Treating, and Col. C. L'H. Ruggles for the Ordnance Department. Short addresses were also made by Mr. Calvin W. Rice, Secretary of the A. S. M. E., and Prof. W. H. Kenerson, Dean of Engineering at Brown University.

For Saturday morning, May 28, a blind bogie handicap golf tournament was arranged on the Rock Island Arsenal Golf Club course.

Simultaneously with the golf tournament, those members who did not play were taken on side trips to plants and points of interest in the vicinity, and at 1:30 P. M. the visitors gathered for a farewell luncheon at Terrace Gardens, Davenport, Iowa.

Everyone expressed themselves as being greatly pleased with the visit to Rock Island Arsenal, and the Tri-Cities, both from a professional and entertainment standpoint, and it is felt that considerable impetus was given to the projected Tri-Cities Engineers Club by the visit of these engineers from various parts of the country.

Airplane Bombing

By

E. J. LORING

Member A. O. A.

TEN years ago, when airplane meets were first held in this country, one of the usual events on the program was a "bombing" exhibition in which "bombs"—oranges or paper bags filled with flour—were dropped overboard by hand from a few hundred feet altitude against a target outlined on the ground. Shortly before the Great War a prize offered by Michelin in France for best bombing was won by a former officer of our Army. In 1914 our Army made its first bombing tests at San Diego, and later dropped some bombs at the Mexican border. In the early days of the War, the offensive use of the airplane was in dropping small bombs, launched overboard by hand and smaller objects, such as steel darts, released in quantities, and incendiary grenades. From these minor offensive weapons, bombing has grown in the past five years until to-day it has the most powerfully destructive unit weapon of any branch.

With the increase of size and power of the airplane and of the bombs, there have continually arisen new problems in stowing, slinging and releasing the bombs. Yet, through it all, there remains the fact that the object of all this development and of every bombing expedition is to register a destructive hit upon a desired target and except as affecting morale, all the time and expense of production and transportation of bombs and planes, of training of personnel, and the risks of the expedition, are wasted in proportion as the bombs fail to reach the target.

From the few hundred feet altitude of the early airplane flights the bombing level for land planes has been pushed higher and higher, so that at present the normal altitude for day bombing is around fifteen thousand feet, for night bombing about one-half of that, and naval bombing usually from one thousand to two thousand five hundred feet, running somewhat higher against strongly defended ships. The head of an ordinary pin held at arm's length covers a circle of 50 feet diameter, as seen from 15,000 feet, a circle which will enclose the ordinary farm house and which is about the size of the crater in soft soil from a 500-pound bomb, and thus represents about the area of full destructive effect which should touch the target. The bomber is taking his aim from a rolling airplane, while traveling toward such a target at a speed of from 60 to 150 miles per hour, traversing that limited area in from one-fifth to three-fifths of a second.

Still worse for accuracy if we think of the bomber as shooting at a moving target with a gun fixed vertically while he himself is fixed in space—and this is the way it looks to him—he cannot point his gun, but can only await the proper time ahead of the target for release. True, he can determine the actual direction of travel of the plane in relation to the ground, and if it is not correct he can communicate by signal with the pilot so that the actual direction—not the apparent direction, the axis of the plane—may be toward the target. But he has no direct control whatever of the direction for line and further, both for line and range, he must make constant reference to the vertical, since the bomb when released has only the forward motion of the plane to which is gradually added a vertical motion through the action of gravity, so that the path of the bomb in falling is a curve in a vertical plane through the path of the airplane at the point of release. Now the sense of vertical is nearly lost in an airplane; no pendulum or spirit level can give it, but will only indicate an apparent vertical, which departs from the true vertical on every turn, bump pitch or side slip of the airplane. Whether on automobile, bicycle, ship or airplane, no course is ever held true and straight, but at best is a succession of curved paths on which an error of direction is accumulated until observable

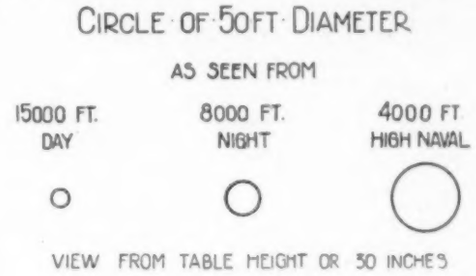


Fig. 1

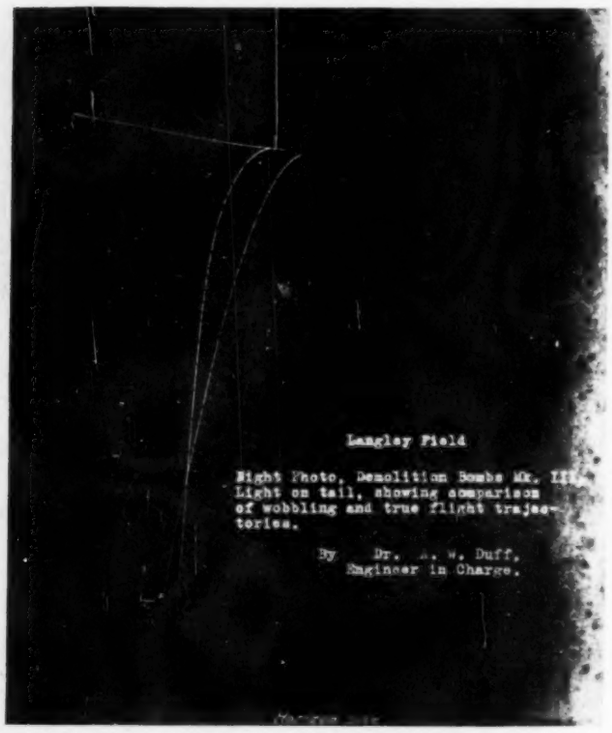
and then corrected. Every curved path means an error in the apparent vertical; for instance, if an airplane be traveling at 100 miles an hour and its path is curving slowly at a rate of one degree in 4½ seconds, or 700 feet, which is a radius of about seven miles, the airplane taking a half hour to turn a full circle, centrifugal force will throw the apparent vertical one degree off from the true, giving an error of 260 feet on the ground from 15,000 feet. So far, there has been but one true vertical observed from an airplane, the reflection of the airplane itself in still water, as found by Maj. F. C. Brown, and used by the Aircraft Armament Division for its trajectory tests.

So the bomber, shooting from his swinging platform at the rapidly moving target, unable to direct his shot except in part by directing the plane itself through the pilot, cannot, by his own senses or by any ordinary apparatus, determine precisely the path of the bomb or the point it will reach, and is in effect shooting with a gun fixed vertically, which he can neither see nor sight.

If any one has doubts as to this difficulty, let him try this: the circles shown in Fig. 1 when viewed from a distance of 30 inches, the height of an ordinary table, present the actual apparent size of a 50-foot circle as viewed from an altitude of 15,000 feet (day bombing), 8,000 feet (night bombing), and 4,000 feet (high naval bombing). Place the sheet on the floor and try to drop a pencil into the circle for 15,000 feet from the level of a table. Place the sheet a few inches out from the table edge, say 5 inches for 15,000 feet to 10 inches for 4,000 feet, and roll a small ball or shot off the table edge to hit the target.

With so serious a difficulty barring the way toward efficient bombing, our development at present is toward the use of a gyroscope to give a vertical reference line or to position the sighting apparatus, not because the gyroscope has done this, or can readily do it, for it has its own troubles, but because it offers the most, if not the only promise at present. These are almost invariably driven by

a high-speed electric motor incorporated in the gyroscope wheel, usually by three-phase alternating current from a special generator. Our present developments propose taking power from low voltage direct current from a storage battery, and include also improvements in the manner of


Langley Field
Night Photo, Demolition Bombs Mk. II
Light on tail, showing comparison
of wobbling and true flight trajec-
tories.
By Dr. A. W. Duff,
Engineer in Charge.

True Trajectory

Trajectory in which Bomb wobbled

holding the gyroscope to the vertical and of positioning the sighting apparatus without disturbing the gyroscope, which is very sensitive. Much has already been done, and a satisfactory stabilizer is a prospect of the very near future.

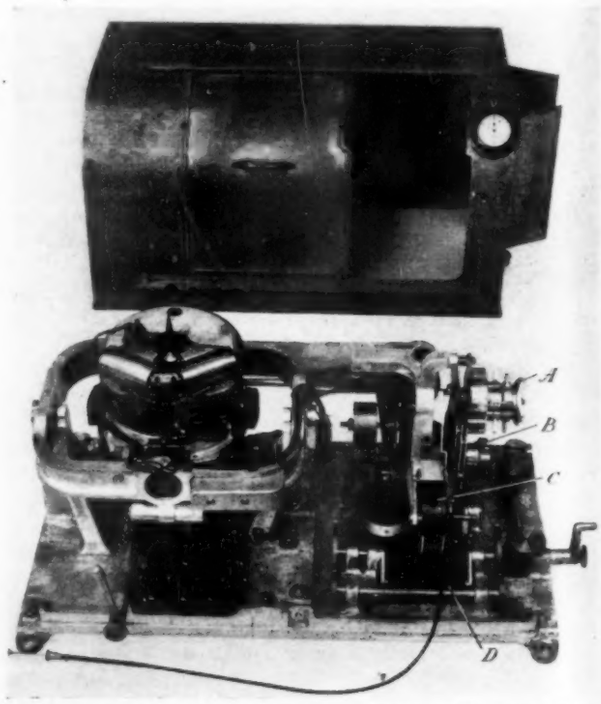
In addition, there is the sighting apparatus itself—the bomb sight—which has a multiplicity of functions. The fundamental purpose is to indicate at all times the point on the ground which would be hit by a bomb released at that instant, assuming that the apparatus is held in the true vertical. If the desired target lies to one side of the point indicated, the bomber is helpless; if it lies ahead, but off the course, the course of the plane can be changed; if it lies ahead on the actual path of the plane—usually at an angle with the axis of the plane due to wind—the bomber can only await that instant when it will arrive at the point indicated.

The bomb at the instant of release has only the forward horizontal motion of the airplane, which determines the direction of its path, and if there were no air resistance the bomb throughout its fall would be always directly under the airplane and the forward travel of the bomb in falling would be precisely the same as that of the plane for the same time. Due to the resistance of the air, the bomb usually lags both vertically and horizontally, so that it gradually falls behind the position of the airplane, this distance at the ground being called the "trail."

The complete bomb sight is required to determine the speed and direction of the airplane and of the wind in relation to the ground; to show the proper apparent direction of flying to reach a given target; to communicate this direction to the pilot, and to indicate to the bomber, as stated above, the point on the ground which would be hit by a bomb released at that instant, taking account of ground speed, wind speed and direction, air speed, altitude and the bomb's characteristics and air resistance.

The bomb itself is an elongated body with vanes at the rear end to prevent the bomb from setting itself across its path with greater resistance. But the path is a curve, turning from a horizontal motion at the start to a direction nearly vertical at the ground, and the bomb is thus compelled to change its position in the air. This tends to introduce oscillations in the path, and in many cases the bomb lags behind the curvature of its path so that it "skids" or actually travels at times ahead of the vertical from the airplane, though greatly retarded vertically; or, on the other hand, the bomb may swing until it noses downward from the curve of its path, so that its forward velocity tends to push it down faster, at the expense of its forward travel. These variations are a source of great difficulty as they cannot be predicted, but fortunately these effects are much reduced with increase of size. Accurate bombing does not require that the bomb follow a certain path, but rather that a given type of bomb will always take the same path, so that its point of hit may be predicted. The study of the behavior of the bomb while in the air is full of great difficulties, and we have not yet determined all the conditions which are necessary to give it the greatest possible regularity in flight.

It is hoped that these remarks may make clear, that while it is a very simple matter to drop a bomb from an airplane, just as it is simple to pull the trigger of a gun, it is by no means so simple a matter to do so in a manner to register a hit upon the target. It requires good training and steady nerves, personnel of an entirely different nature from that of a chasse pilot, sighting apparatus of a very special nature, steady airplanes, and a very careful proportioning of the bombs for steady flight; for a given destructive effect, good bombing means conservation of planes, supplies and personnel.



Mark X Bomb Sight and Stabilizer, with Collimator and Universal Scales

A. Collimator
B. Altitude setting
C. Trail-Altitude-Time Setting
D. Glass Plate in Base

Telescopic Musket Sights

By

H. K. RUTHERFORD

Member A. O. A.

PRIOR to the War, the subject of developing a suitable telescopic musket sight for the service had been given considerable attention, and certain fairly definite ideas had been formed regarding the desirable features of such an instrument. The War interfered with the program of development somewhat, for the reason that in the early months musket sights were considered to have little value on the battlefield, and the energies of all concerned were devoted to procuring materiel absolutely essential to the equipping of the troops. As soon as it became apparent, however, that the sniper had become a factor in the contest, steps were taken to develop a design which could be produced in quantity sufficient to meet the needs of the services. The Armistice prevented the carrying out of this program, but the development work started has been continued to date, and since some definite conclusions can now be drawn from the tests made, it appears advisable, at this time, to review the progress made.

The writer does not lay claim to any expertness in the use of the rifle in the field, hence takes the official reports from the service as a basis and will confine his discussion chiefly to a description of the sights developed by the Ordnance Department to meet the recommendations of the service and to remarks on the most promising lines of future development from an ordnance standpoint.

Advantages of Telescopic Sights. The question may well be asked, "What value has a telescopic musket sight over an open sight to compensate for its greater initial cost, additional weight and bulk, and its liability to injury or disarrangement?" The advantages may be briefly stated as follows:

(a) The rifle can be laid on a given target with increased accuracy. The average unaided eye can at best distinguish between two points about one minute of angle distant from each other. The use of a telescope increases this resolving power, depending chiefly on magnification, so that points closer together may be distinguished.

(b) The increased light-gathering power of a good telescope over the naked eye enables one to see objects through it which are invisible to the unaided eye.

(c) The fact that the cross-wires in the telescope appear to be projected upon the distant target, eliminates the eye strain encountered with the iron sights due to the effort to see rear sight, front sight and target all at the same time.

The chief disadvantages of telescopic sights are as follows:

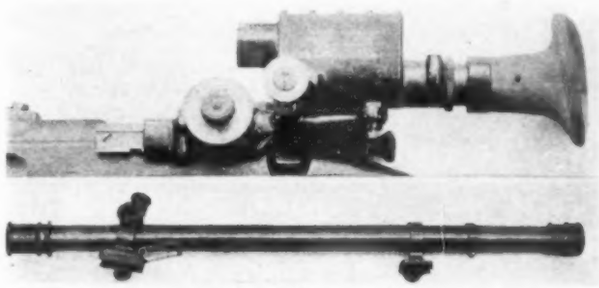
(a) Its field of view is limited. In any telescope the field varies inversely with the magnification. In musket sights, even those of the best foreign design, the field of view in degrees does not exceed the quotient of 25 divided by the magnification, and in many good sights it is less than this.

(b) Even if the telescope is well designed, the eye must be placed in a definite position with respect to the eyepiece in order to get the full field, and this tends to reduce the rate of fire.

(c) A good telescope is expensive to manufacture and must be handled carefully to avoid injury.

The following descriptions cover in chronological order the most important telescopic musket sights given official tests in this country in recent years.

The Warner & Swasey Telescopic Musket Sight. This sight was developed by the Warner & Swasey Co. in 1906, and was adopted as the standard service musket sight in 1908. It exists in two models—the 1908 and the 1913—which differ from each other only in minor details of construction, although the later model is slightly superior optically. It is shown mounted on the rifle in Fig. 1.



Above: Fig. 1. Warner & Swasey Telescopic Musket Sight, Model 1913
Below: Fig. 2. Winchester 5A Telescopic Musket Sight

The details of this sight are covered in Ordnance Pamphlet No. 1957, and need not be repeated here. It will be sufficient for our purposes to state the following characteristics:

Magnification	5.2
Aperture of objective	.77
Field of view	4.5°
Diameter exit pupil	.15
Longitudinal eye relief	1.7
Erecting system	Two Porro Prisms
Weight	2 lbs. 2⅝ ozs.

The sight is mounted rigidly on the rifle. Range and deflection are set off on knobs which move the entire telescope with respect to the supporting bracket. The eyepiece is adjustable for focus by the user.

The chief objections to this sight as found in the service are:

(a) The eyepiece is offset to the left of the center of the rifle about 1.75 inches so that the user must assume an uncomfortable position.

(b) The longitudinal eye relief is so small that the user is liable to injury in firing in spite of the rubber eye shield.

(c) The power is higher than necessary and the field of view correspondingly smaller than desirable.

(d) The exit pupil is too small, hence it is a poor night glass.

(e) The sight is heavy and bulky.

(f) The glass reticule is easily obscured by film and moisture which gathers in the telescope in spite of all efforts to prevent it.

In view of the above defects, efforts have been made from time to time to develop an improved type of sight. In 1915 the School of Musketry made a comprehensive test of all available types of musket sight and submitted a report under date of December 18, 1915. The following sights were tested:

(a) The Winchester 5A Sight with Side Mounting.
(b) The Winchester 5A Sight with Top Mounting.
(c) The Warner & Swasey Telescopic Sight.
(d) The C. P. Goerz Telescopic Sight.

The Winchester 5A Sight (Fig. 2) has long been familiar to riflemen in this country. It consists briefly of a straight telescope 7/8 inch in diameter and 15 7/8 inches long, having the eyepiece and objective both adjustable by the user. The principal optical characteristics are as follows:

Magnification		5.33
Aperture of objective		.48
Field of view		3.26°
Diameter exit pupil	inches	.09
Longitudinal eye relief	inches	2.02
Erecting system		Lens

The sight is located by its supporting brackets directly over the center of the rifle, and clears the receiver 5/8 of an inch. Two brackets are provided, a front one, located on the Model 1903 rifle about midway between the lower band and the rear sight, and a rear one, located on the fixed base

Above: Fig. 3. Goerz Telescopic Musket Sight (Left Side View)
Below: Fig. 4. Goerz Telescopic Musket Sight (View looking down on Rifle from above)

in place of the rear sight, which is removed. The rear bracket carries the range and deflection knobs, by means of which the whole telescope is adjusted about the front bearing as a center. The telescope is free to slide through its bearings, and since these bearings are located about 6 inches apart on the rifle, a total longitudinal mount of about 9 inches is permitted to the sight. During the recoil of the gun the sight slides forward through the bearings and must be brought back to its rear position by hand before the next shot. The fact that the sight is free to move has the following advantages:

(a) Relieves the sight of the severe shock that it would receive if rigidly attached.
(b) Removes the risk of injury to the eye from striking the sight in spite of the moderate longitudinal eye relief.
(c) When the sight is pushed forward as far as possible, the magazine is cleared and the piece may be loaded by clip.

The School of Musketry in the 1915 tests found the following objections to the Winchester Sight:

(a) The field of view is so small on account of the excessive power as to seriously affect its usefulness, except for slow fire at fixed targets, for which work it was considered excellent.
(b) The spacing of the brackets only 6 inches apart on such a long telescope is considered a source of weakness.
(c) The bolt of the rifle cannot be operated unless the telescope is pushed forward about 2½ inches from its firing position. This fact and the necessity of drawing the sight back to the firing position after each shot materially increases the time of firing.
(d) The exit pupil is so small that the sight is of no use in a poor light.

For the above reasons, the School of Musketry reported that the Winchester 5A Sight was not considered available for general military use.

The C. P. Goerz Musket Sight. This sight mounted on a U. S. Model 1903 Rifle was obtained from C. P. Goerz Company, of Berlin, in August, 1913, and after a preliminary test and a relocating of the sight on the rifle, was submitted to the School of Musketry for the competitive test above referred to. It is shown in Figs. 3 and 4.

It consists of a straight telescope 10 7/8 inches long, 1 inch in diameter for 8 inches from the objective, then expanding to 1½ inches to accommodate an eyepiece of 1 5/8 inches in diameter. The focus is universal. The following are the chief characteristics of the optical system:

Aperture	inches	.80
Power	diameters	3.2
Field of view	degrees	8.45
Diameter exit pupil	inches	.25
Longitudinal eye relief	inches	2.76
Erecting system	lenses	2

The telescope is of the moving reticule type. Ranges are set on a graduated knob on the top of the tube, which, by means of a screw, gives a corresponding movement to the reticule. Deflections are set by moving the entire telescope under the action of the deflection screw located in the front support of the telescope.

The sight is attached to the rifle by means of a steel slide with beveled edges, secured to the left side of the receiver in a manner similar to that of the Warner & Swasey sight. The lower edge of this slide has three notches, permitting three positions of the telescope.

The telescope itself is firmly attached by a front and rear bearing to a bronze support which dove-tails over the steel slide above referred to and is locked to the same by a spring catch. The front bearing of the telescope carries the deflection worm and knob, and the rear bearing consists of a vertical pivot about which the deflection movement is made. The location of the parts is such that the line of sight is .89 inch to the left of the center of the bore, so that the telescope clears the well and the bolt handle, and does not obstruct or interfere with the iron sights.

The reticule (D Fig. 15) consists of a heavy vertical pointed stud extending from the bottom of the field to the center, and of two heavy horizontal wires and a vertical one extending from the edges to within a short distance of the center. This arrangement leaves the center of the field clear and gives a sharply defined point on which to bring the target.

Conclusions of the School of Musketry. The report of the School of Musketry states that in its opinion this sight possesses all the essential requirements of such an instrument, viz., power, definition, field, ready adjustment, simplicity, strength, rigidity and convenience to the user, and that for military use it is as much superior to the Warner & Swasey type as the latter is to the Winchester 5A Model. The points of its superiority are:

1. Position on the rifle,
2. Method of adjustment,
3. Rigidity,
4. Effect on the loading operation,
5. Elevating device,
6. Windage device,
7. Accuracy while in use,
8. Field of view,

9. As a general target sight,
10. As a field sight,
11. General serviceability,
12. Availability for military use.

Recommendations. The recommendations of the School of Musketry were:

(a) That the Goerz Telescopic Sight be adopted for issue, replacing the Warner & Swasey Sight.
(b) That they be issued at the rate of two to each organization of the mobile army armed with the rifle.

Acting on the recommendations of the School of Musketry, the Chief of Ordnance, in February, 1916, communicated with the representative of the C. P. Goerz Company in this country relative to the conditions under which that firm would permit the manufacture of the sight in the United States. The communication was acknowledged, but no further reply was received.

To determine if there was any reason why the Goerz Sight could not be manufactured with the facilities and materials available in the United States, drawings were prepared at Frankford Arsenal, from the sample sight, and one sight was manufactured and called Telescopic Musket Sight, Model 1916, No. 1. This sight has proved in limited tests that it is quite as satisfactory as the original Goerz Sight, although in a report by the School of Musketry under date of June 26, 1917, objection is made to the fact that the telescope is offset too far to the left of the center line of the rifle.

On account of the pressure of more essential work, and the apparent lack of demand on the part of the service for musket sights, little further action toward producing the Goerz type was taken until March, 1917. At this time a representative of the Winchester Company stated that he believed his concern to be in a position to develop an improved sight which would equal the Goerz optically and would be an improvement on the Goerz in certain respects, and which could be produced more readily in quantity. The drawings of the Goerz Sight prepared at Frankford Arsenal, also the general specifications of the same, were turned over to the Winchester Company in April, 1917, and permission was given it to proceed with the experimental work.

A sample of the improved sight (Fig. 5) was tested by a Board of Officers convened at Camp Meade, Maryland, and report submitted under date of April 20, 1918.

The improved, or Model 1918 Sight, is very similar in construction and method of mounting to the Winchester Model 5A, but is only 10⅞ inches long. The main optical characteristics are as follows:

Aperture of objective	inches	.56
Magnification	diameters	2.6
Field of view		8° 22′
Diameter exit pupil	inches	.2
Longitudinal eye relief	inches	2.25
Erecting system	lenses	2

The sight is permitted a longitudinal movement of about one inch in its brackets under the action of recoil. The method of mounting is such that the rear sight of the rifle must be removed, the bolt handle modified, a modified form of lock furnished, the bridge of the receiver changed, and the cutoff modified slightly to clear the rear bracket.

The Board at Camp Meade had also before it the C. P. Goerz Sight above referred to, the Winchester Model 5A, the Warner & Swasey, Model 1913, and a new model of Warner & Swasey Sight identical to the 1913 model except in power, which was decreased to 3 diameters with a consequent increase in field. There was also considered the Casey-Czegka Sight, which will be described more in detail later under the name of Casey Sight.

The Board reported that the 2.6 power Winchester Sight was in its opinion superior to the Goerz model in all essentials, such as the following:

(a) Size,
(b) Optical qualities,
(c) Position on the rifle,
(d) Rigidity of mounting,
(e) Method of setting range and deflection,
(f) Lateral and longitudinal eye relief,
(g) Adjustability of objective and eyepiece,
(h) Maintenance of accuracy under test.

The Board also commented on the following undesirable features of the Winchester Sight:

(a) Necessity of modifying the rifle,
(b) Necessity for discarding the iron sights,
(c) Impossibility to load by clip.

The recommendations of the Board were that the Winchester 2.6 Power Telescope be adopted for issue in place of the Warner & Swasey Model 1913 Sight, and that none of the other sights tested be adopted.

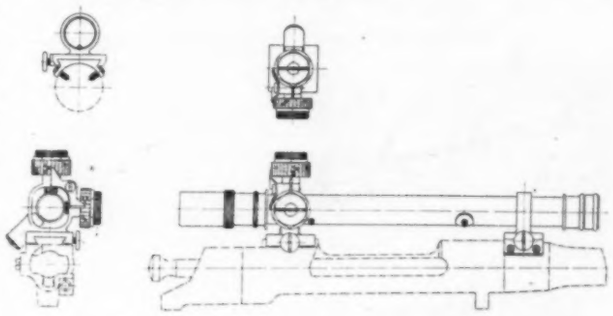


Fig. 5. 2.6X Winchester Telescopic Sight, Model of 1918

Based upon the above recommendations, orders for a large quantity of the new sights were placed with the Winchester Company in the summer of 1918, and arrangements for quantity production were being pushed when the Armistice was signed. A large portion of the order was then cancelled and work continued very slowly on the balance until October, 1919, when three sights were completed and forwarded to the School of Musketry at Camp Benning for further test.

This test soon developed a number of weaknesses in the sight, which led the Infantry School to recommend against its adoption until they had been remedied. These defects were:

(a) The optical parts shot loose and the lenses became uncemented, rendering it impossible to see through the telescope.
(b) The rear bracket was fractured by the recoil.
(c) If the user neglected to draw the sight back to the firing position each time, he was liable to injury from the rebound of the telescope.

Frankford Arsenal Types Nos. 1, 2, 3 and 4. Steps were then taken by Frankford Arsenal to manufacture sample sights which would overcome the above defects, and four telescopes were produced, each having the same optical system as the Model 1918 Winchester. Two of these telescopes (Fig. 6) were provided with adjustable eyepiece and objective and two were non-adjustable, as shown in Fig. 7. Two of the telescopes (Fig. 6) were provided with a spring recuperator, shown just in rear of the front brackets, so designed as to return the sight automatically to the firing position after each shot; in the other two (Fig. 7) this operation had to be performed by hand, leather buffers being provided to limit the forward movement of the telescope. The mountings for the lenses in all four telescopes were redesigned to hold these parts more securely, and this ne-

cessitated the use of a larger tube for the telescope body.

The front and rear brackets were redesigned to increase their strength, and more reliable clamps for securing them to the rifle were provided. Two types of rear brackets were furnished, first, that shown in Fig. 7, which is practically the same as the Winchester, Model 1918, except that the range and deflection indices are made separate and a spring detent is provided to prevent accidental movement of the knobs; and second, that shown in Fig. 6, in which a different type of range and deflection knob is furnished. It will be noted that the range index on this type, instead of being a simple pointer, consists of a strip graduated in minutes of elevation to 10 on each side of the normal. This idea is

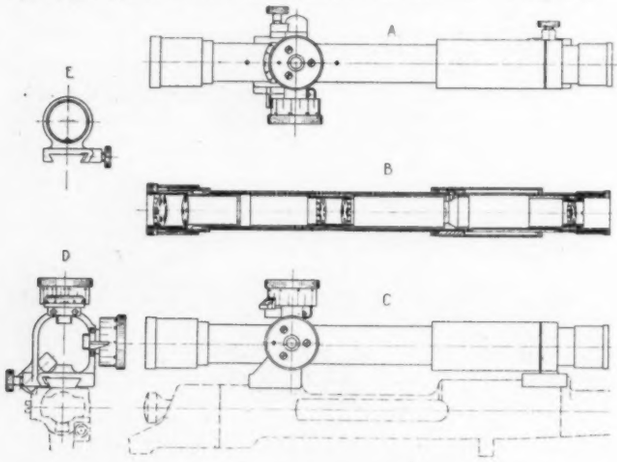


Fig. 6. Frankford Arsenal Experimental Musket Sight (With Adjustable Eyepiece and Objebtive)

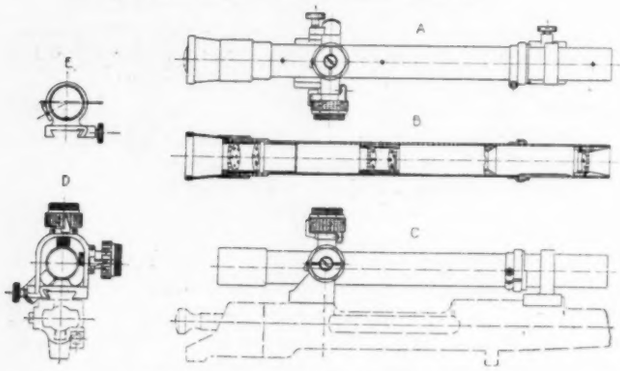


Fig. 7. Frankford Arsenal Experimental Musket Sight (With Non-Adjustable Eyepiece and Objective)

one patented by Maj. S. A. S. Hammar, and was included in the design at the request of the Infantry School. The advantage claimed for it is that it gives a convenient means for adjusting the range in terms of minutes of elevation.

The clamping screws on both types of rear bracket were moved to the left side, where more room was available.

The Casey Sight. This model was developed at the same time as the four sights above referred to, but due to difficulties in design and manufacture was not completed for some weeks after Nos. 1, 2, 3 and 4 had been sent to Camp Benning for test. Credit for the method of mounting involved is due to Major K. K. V. Casey of the Du Pont Company.

The main feature of this sight (Figure 8) is that the body of the telescope is mounted on the side of the rifle by means of a bracket similar to that used with the Warner & Swasey Sight and the eye-piece is brought up to a position as nearly as possible over the center of the piece by means of an offset prism in the optical system. The telescope slides forward in its bearings under the force of recoil and is brought back to the firing position by a coil spring in the housing on the rear bracket. The sight has the additional feature that the eye-piece may be rotated outward and downward to the left side of the rifle where it is out of the way. The optical system is the same as that of the Winchester Model 1918 Sight, except that the offset prism is added. Range and deflection are set by moving the telescope as a whole about its rear bracket as a pivot. The range and deflection screws are the same as those shown in Figure 6.

The advantages claimed for this method of mounting are:

(a) The sight is easily attached with practically no modification to the standard rifle.

(b) The iron sights are left clear for use by simply rotating the telescope out of the way.

(c) In its normal sighting position, the telescope does not interfere with the operation of the bolt or with loading by clips.

(d) The position of the telescope is such that the field of view is not obscured by heat waves from the barrel.

(e) The telescope is less liable to injury on the side of the rifle than on the top.

The chief disadvantages of this sight from a standpoint of construction are:

(a) Its increased cost.

(b) The liability of shooting the prism and eye-piece loose due to the offset.

(c) Its possible unreliability due to the amount of mechanism involved.

The sample sight was completed and shipped to Camp Benning for test in August, 1920. Many difficulties were encountered in its construction and when finished it was not as good optically as the preceding four telescopes. Since its completion, however, an improved optical system has been worked out which, when mounted in the Casey Sight, will make it the equal, optically, of the No. 7 Sight described below, and considerably superior to designs Nos. 1, 2, 3 and 4.

Frankford Arsenal No. 7 Telescope. A preliminary report dated June 8, 1920, on the four Frankford Arsenal Sights, above referred to, outlined certain defects and recommended that another sight be constructed to eliminate them. These defects were:

(a) Too short longitudinal eye relief.

(b) The spring recuperator brought the sight back to the firing position too violently.

(c) Reticule not satisfactory.

(d) A rear mounting with deflection knob on the left was desired for test.

As a result of the above recommendations, the Frankford Arsenal No. 7 Sight (Fig. 9) was developed. The optical system was entirely redesigned so as to obtain the following characteristics:

Aperture of objective	.50
Magnification	diameters 2.5
Field	sharp to edges 7°
Exit pupil	inches .20
Aperture of eye-piece	inches .95
Longitudinal eye relief	inches 2.87

Its chief superiority optically over the Winchester Telescope is in increased longitudinal eye relief and in the extent of the clear field.

The objection to the shock of counter recoil was overcome by placing a leather buffer on the telescope in front of the front bracket. A rear bracket with deflection knob on the left was furnished and an improved reticule was inserted, but otherwise the sight is the same as the recuperator types Nos. 3 and 4, above described. This sight was shipped to Camp Benning in September, 1920, to-

gether with the Zeiss Prism Sight described below. This sight is still undergoing test.

Zeiss Prism Sight. This telescope was received from overseas with a shipment of captured material. Its optical qualities were so excellent that it was considered advisable to mount it on a rifle so that it could be tested with the other types. This sight with its improvised mounting is shown in Fig. 10. It differs from the other types previously described chiefly in that it utilizes a special roof-edge prism as an erector in place of the usual lenses, and has an unusually large, adjustable, eye-piece. The optical characteristics are as follows:

Aperture of objective		.59
Magnification	diameters	2.03
Field	clear to edge	12.2°
Longitudinal eye relief	inches	2.8
Diameter exit pupil	inches	.29
Diameter eye lens	inches	1.20

The eye-piece of this sight is manufactured of special glass, not available in this country in quantity, and this makes possible a somewhat greater eye relief than is obtainable with domestic glass in the F. A. No. 7 with an eye-piece of the same diameter.

On the original sight, range was set by moving the objective by means of a knurled collar which carried the range graduations. No means for setting deflections was provided. As originally used abroad the sight was apparently mounted rigidly on the rifle by one point of support as shown in Fig. 11.

On the sight as mounted for test at Camp Benning, Fig. 10, a front and rear bracket are provided, through which the sight slides during recoil. The usual spring recuperator brings it back to the firing position. Range and deflection are set by the usual knobs on the front bracket by means of which the telescope is moved as a whole about the rear bracket as a pivot.

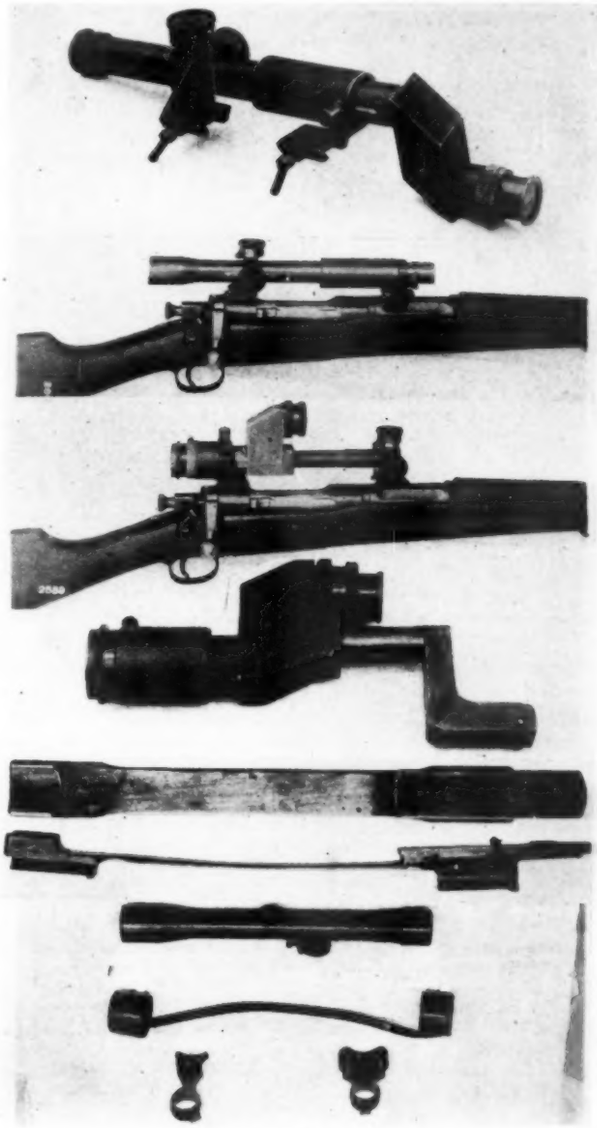
The test of this sight has not yet been completed.

The Modified Casey Sight. As stated above, the optical system mounted in the original Casey Sight was not equal to that developed for the Frankford Arsenal No. 7 Sight which was produced after the completion of the Casey Model. To improve it in this respect, the sight has been returned to Frankford, where it will be given the same optical system as No. 7 telescope and have certain minor changes made in the mounting, preparatory to a final test at Camp Benning. A leather buffer is also being assembled to the tube to reduce the force of counter recoil, and an improved type of reticule will be assembled.

The Knoble Sight Mounting. There is shown in Fig. 12 a type of telescopic sight mount known as the Knoble Mount, now undergoing test at Camp Benning. It consists mainly of a block machined to the dimensions of the rear sight movable base on the Model 1903 rifle, which can be attached to the rifle in place of the movable base. At the rear end of this block is a leaf spring which extends back over the chamber and snaps over the bridge of the receiver, holding the whole device securely in place. Mountings for a straight telescope are fitted to the top of the device at front and rear.

The tests so far made indicate that this sight mounting furnishes a rigid and convenient means of attaching a straight telescope to the rifle without requiring any modification whatever to the latter.

An English Sight. There is shown in Fig. 13 a telescope purchased recently in England, which differs from the Goerz model, above described, only in the method of mounting. The English Sight is attached rigidly by two brackets on the telescope to corresponding sockets mounted on the rifle, one near the rear sight and the other on the left of the bridge of the receiver. Range and deflection are set in the same manner as in the Goerz Sight, viz.: by moving reticule and outside deflection screw respectively.



Reading from Top to Bottom
Fig. 8. Casey Musket Sight
Fig. 9. Frankford Arsenal Experimental Musket Sight No. 7
Fig. 10. Zeiss Prism Musket Sight (On Frankford Arsenal Mount)
Fig. 11. Zeiss Prism Musket Sight as Originally Mounted
Fig. 12. Knoble Mount for Telescopic Musket Sight
Fig. 13. British Musket Sight—Goerz Pattern

The telescope is somewhat smaller than the Goerz and has the following optical characteristics:

Aperture of objective	inches	.48
Magnification		2.75
Field of view		70°
Diameter exit pupil		.175
Longitudinal eye relief		3.42

So far as known, this sight has not yet been tested in this country, nor is it known if it is an accepted type abroad.

SUMMARY

The following sights have been discussed above in more or less detail:

(a) Warner & Swasey Musket Sight, Models 1908 and 1913.

(b) The Winchester Model 5A Sight.
(c) The C. P. Goerz Sight.
(d) The Telescopic Musket Sight, Model 1918 (Winchester).
(e) Frankford Arsenal Nos. 1, 2, 3 and 4.
(f) The Casey Sight, Original and Modified.
(g) The Zeiss Prism Sight.
(h) Frankford Arsenal No. 7.
(i) The Knoble Mount.
(j) English Sight of Goerz Model.

These sights represent quite a variety of optical systems of varying degrees of excellence and so far as known include the best types that have been developed to date either abroad or in the United States. Each of the different methods of mounting has points in its favor as well as objectionable features, and it is the object of this article to review the tests of the different optical systems and methods of mounting to determine, as far as practicable, the line that development should take to produce a sight embodying as many desirable features as possible with a minimum of undesirable ones.

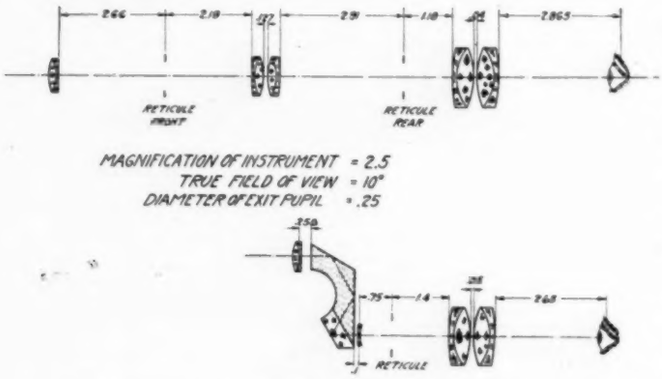


Fig. 14. Comparative Optical Lay-Out of Straight Telescope and Zeiss Pattern

The Ideal Optical System. It may be stated quite confidently as a result of the tests so far made that the following should be the optical characteristics of a satisfactory telescopic musket sight:

Magnification—2 to 3 diameters.
Field of view—not less than 7° and as much more as practicable.
Diameter of exit pupil—about .25 inch and more if practicable.
Longitudinal eye relief—not less than 2.5 inches for the rigid type of mount. The sliding type of mount requires less eye relief.
Diameter of Eye-piece—depends directly on the longitudinal eye relief and the size of the field. It should be kept as small as practicable so that the line of sight may be kept close to the axis of the bore.

The Goerz Sight, the Zeiss Prism Sight and the Frankford Arsenal No. 7 approach more closely than any of the others the specifications given above for the ideal optical system. The Goerz Sight has a magnification higher than is perhaps necessary, while the Zeiss has a power of only 2 diameters, which enables it to show an unusually large field. The Frankford Arsenal No. 7 has too small an exit pupil and a rather limited field, but can be made equal to the Zeiss if the magnification is reduced to that of the latter.

It may be concluded that these three sights represent the best that may be expected in the present state of progress in the optical art.

Comparison of Straight Telescope with Prism Type. Since the Goerz Straight Telescope and the Zeiss Prism Sight are about equally efficient, the question arises which type will be more satisfactory from the standpoint of manufacture and upkeep in service.

An optical layout of a sight of each type with identical optical characteristics is shown in Fig. 14. Practically the only effect the prism has is to eliminate the two erector lenses of the straight telescope and to offset the line of sight. The disadvantages of the prism are:

(a) It is much more difficult to hold rigidly in the telescope than the two lenses.
(b) The Zeiss Prism is much more expensive to manufacture than the lenses.
(c) The mount for the prism type is much more expensive to manufacture than the other.

Unless, therefore, there is some very substantial advantage to be gained by offsetting the line of sight, the straight telescope is to be preferred to the prism type. This leads us to a discussion of the ideal type of mount.

Ideal Type of Mount. The results of the tests so far held indicate that a satisfactory mount should fulfill the following conditions:

(a) Should locate the eye-piece so that the user can assume a comfortable position. This requires that the line of sight should be as near that of the iron sights as possible.
(b) It should require a minimum of alteration to the rifle for the assembly of the sight.
(c) It should be easily removable and then permit the iron sights to be used.
(d) It should be compact and light and yet so rigid that it will not change position during firing.
(e) It should be arranged so that the sight may be removed and replaced in the middle of a score without requiring any change in the range and deflection settings.
(f) It should not interfere with the operation of the bolt nor, if practicable, with that of loading by clip.

Defects of Sliding Mount. Due to the amount of mechanism required for the sliding type of mount and the fact that lack of cleaning, wear, etc., would in all probability affect the relative positions of the moving parts, a non-recoiling type of mount is to be preferred, if the telescope can be constructed to withstand the shock of rigid mounting. Tests made in this country with sights rigidly mounted and the fact that it is apparently the general practice abroad to mount sights rigidly, indicate that this method is entirely practicable. We conclude then that the non-recoiling mount is to be preferred.

Range and Deflection Mechanisms. The accuracy of the whole instrument depends to a great extent on these mechanisms and they should, therefore, be not only rigidly constructed but protected from possibility of injury due to dirt getting on threads, etc., and from the effects of wear.

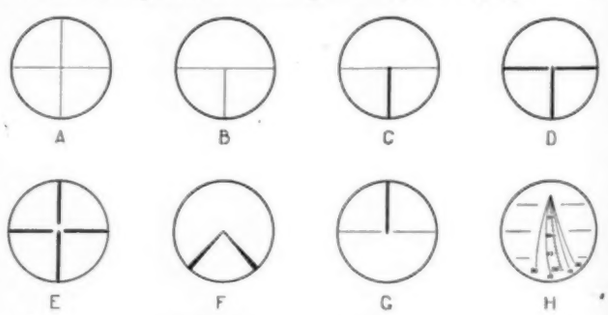


Fig. 15. Various Types of Reticules

Range and deflection may be set in one of the following ways:

(a) By moving the telescope as a whole, as in the case of the Warner & Swasey, Winchester, Casey and F. A. sights above described.
(b) By moving the objective or the reticule as is done for range in the case of the Zeiss Prism and the Goerz Sights respectively.
(c) By a combination of both the above as is the case of the Goerz Sight.

The method of setting range by means of a moving reti-

cule appears most practicable for the following reasons:

(a) It is compact, accurate and convenient.
(b) The mechanism can be perfectly protected from accidental damage due to entrance of grit, etc.
(c) Tests have shown it can be so constructed as to withstand service on a rigid mounting.
(d) The holding position is not disturbed when ranges are set as would be the case if the telescope as a whole were moved.

It would, at first glance, seem advisable to set deflections also by means of a moving reticule, but this is open to the objection that a complicated mechanism would be required to give the vertical post movements in both directions. This mechanism could not be made dust and water proof and it would in all probability shoot loose.

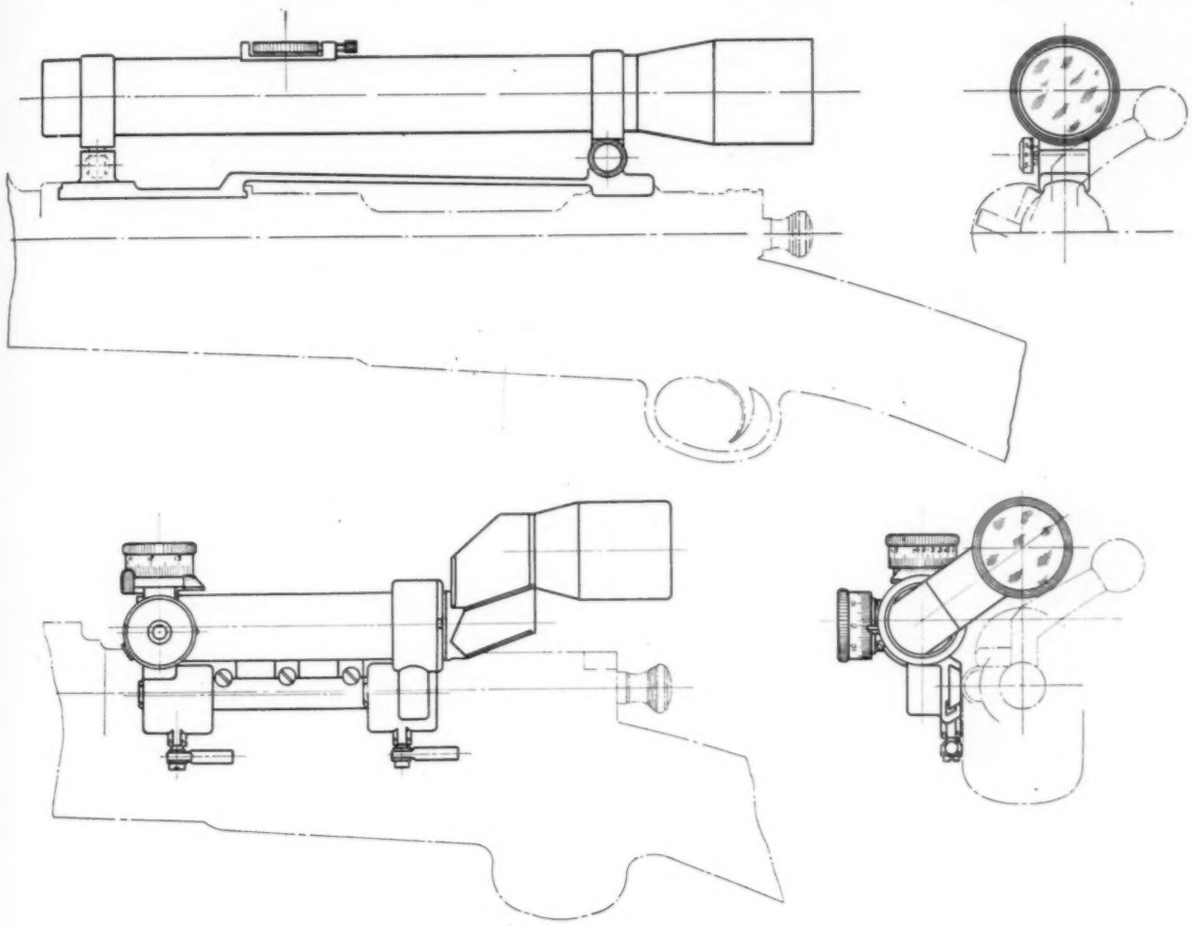
If two plain cross-wires were used for the reticule, however, the horizontal one could be set in the front focal plane of the Goerz Sight and the vertical one in the rear focal plane, or vice versa. The two wires could then be set separately by range and deflection knobs and the intersection would indicate the line of sight. This simple form of reticule appears open to the objection that the intersection of the wires would obscure the exact point to be aimed at, unless they were made very fine, in which case they would be invisible in a dim light.

The moving objective type of adjustment is open to the objection that it cannot be made as waterproof as the moving reticule and would necessitate the enlarging of the front end of the telescope.

It appears, therefore, that the most practicable method of arranging for the deflection adjustment is by means of an outside worm and knob which move the telescope as a whole. This is the method used in the Goerz mounting above referred to. Since the amount of movement in deflection is small, the mechanism can be made very compact and rigid and can be protected to a great extent from injury and the effects of wear, so that the chief objections to the outside adjustment are minimized.

We conclude then that the Goerz method of setting range and deflection would prove most serviceable.

Ideal Type of Bracket. In our discussion above concerning the relative merits of the prism type and the straight type of sight, we concluded that the straight telescope is to be preferred unless some marked advantage, other than optically, is to be gained by the use of the prism.



Above: Fig. 16. Proposed Design for Musket Sight (Goerz Pattern)
Below: Fig. 17. Proposed Design for Prism Musket Sight

A straight telescope on a mounting such as the Knoble, above referred to, is superior to the prism type with its mount, such as the Casey, in the following respects:

(a) Much cheaper to manufacture.
(b) Much less liability to getting out of order.
(c) More easily attached to a standard rifle.

The Casey type is superior in:

(a) Ease with which the iron sights can be gotten into action.
(b) Facility for clip loading.
(c) Ease of targetting by means of the iron sights.

The two sights can be made equally satisfactory in:

(a) Excellence of optical qualities.
(b) Convenience to the user both as regards position of the line of sight and ease of manipulation.

The advantages seem to be in favor of the straight telescope on the Knoble mount, although the Casey sight has strong points to recommend it.

Reticules. Various types of reticule have been used or proposed for telescopic musket sights. The most common types are shown in Fig. 15, A to F inclusive. B shows the reticule used with the Zeiss Prism Sight, C that used with the Frankford Arsenal No. 7 and D that of the Goerz Sight. Type E seems to be superior to the others in that it embodies all of the following desirable characteristics:

(a) Horizontal wires to assist in preventing canting of the piece.
(b) A sharp point on the central post which can be set accurately for both range and deflection.
(c) An open space in the center which assists in bringing the target to the center of the field and permits a clear view of the exact point to be hit.
(d) Lines heavy enough to show up against even a poorly lighted background.
(e) Wires substantial enough to avoid breaking due to firing.

The G reticule is a proposed one which may have the advantage of showing up against the sky when the light is too poor to permit the D or E types to be used.

The H type is a proposed one which, it is claimed, would eliminate the necessity for range and deflection knobs on the telescope. The method of using would be to place the proper point in the reticule, corresponding to the desired range and deflection as indicated by the graduations, on the target. This type of reticule has already been used in various artillery sights, but is open to the objection that the gun pointer is required to concentrate his mind on the target and on the graduations at the same time, which is confusing. The graduations also distract the attention and interfere with the vision.

It may be remarked that a glass reticule should not be used in a musket sight, for the reason that under the conditions in service it is almost impossible to prevent moisture from gathering in the instrument and obscuring the reticule. The wire reticule can be made amply strong to withstand the shock of firing and is not obscured by moisture or dirt in the tube.

Adjustable Objective and Eye-piece. Some differences of opinion exist whether the objective and eye-piece should be made adjustable by the user of a telescopic musket sight to accommodate it to short range work and to the needs of the individual eye. For gallery practice work, to avoid parallax in the cross-wires, the objective will require a different adjustment than for long range shooting. For a long or a short-sighted eye the eye-piece will require a different adjustment than for the normal eye. No adjustment of either will correct the vision of the astigmatic eye.

The objections to the adjustable sight are that it is more complicated, hence more likely to get out of adjustment, and it is difficult to provide an adjusting mechanism that will be dust and moisture proof, convenient to use and yet hold its adjustment when once made. The amount of the adjustment required in the eye-piece is small in any case in such a low power instrument as a musket sight and a universal focus should meet all ordinary requirements. If the sight is to be used for gallery practice, an auxiliary lens can be slipped over the objective and so adapt it to any given range.

From the standpoint of manufacture and maintenance, therefore, the non-adjustable sight is much to be preferred. Both the Goerz and Frankford Arsenal No. 7 Sights are of this type and no objection has been made in the various tests to the lack of means for adjustment.

General Conclusions. As a result of the above discussion and the tests so far made, it appears that the ideal telescopic musket sight should be built on the following lines:

A straight telescope similar to the Frankford Arsenal No. 7 or the Goerz, as compact as can be made to obtain the optical qualities outlined below, mounted rigidly on the Knoble type of bracket. Range should be set by means of a movable reticule and deflection by means of an exterior worm moving the entire telescope, as in the Goerz Sight.

The telescope should have non-adjusting eye-piece and objective. The optical characteristics should be as follows:

Magnification about	2.5 diameters
Field	8 to 10 degrees
Exit Pupil	.25 to .30 inches
Longitudinal Eye Relief	2.75 to 3 inches

Since a large field and long eye distance require a large eye-piece, which in turn necessitates raising the line of sight, it may be necessary in practice to reduce either or both the field and eye relief, above specified. The larger exit pupil, which is of advantage in increasing lateral eye relief, may be obtained by increasing the size of the objective, which probably will not be objectionable.

Figure 16 shows a tentative design for the sight as above outlined. Since such a sight has never been actually constructed, there are a number of points in regard to the details to be used in attaching the telescope to the bracket, to be worked out. A compromise must be reached, also between the opposing factors of field, which, with the longitudinal eye relief, determine the size of the eye-piece and satisfactory position of the line of sight, which requires the eye-piece to be small. These points can best be settled by testing type sights and it is therefore recommended that there be manufactured for test a sight similar to Fig. 16 with a power of 2.5 diameters, a field of 10 degrees, or as near that as practicable, an exit pupil of .25 to .30 inch, and a longitudinal eye relief of about 2.75 inches.

Unless the forthcoming tests of the Modified Casey Sight enable a definite decision to be made regarding its desirability as a service sight, it is also considered that an additional sight should be constructed with the same optical characteristics as that of the preceding paragraph, but with a rigid type of Casey Mount. The Zeiss erecting prism would be used in this telescope, since it will serve both to erect the image and offset the line of sight and thus give a considerably brighter image than the Modified Casey Sight.

Fig. 17 shows in a general way how such a sight would appear. In order to reduce the weight carried by the eye-piece, the range and deflection settings are made by moving the telescope as a whole about a ball bearing in the rear bracket, rather than by the moving reticule. The mounting as shown is of the non-recoiling type but arrangements are made so that the eye-piece may be rotated outward and downward to the side of the rifle to clear the line through the iron sights.

Correct Addresses Wanted

Mail addressed to the following members as indicated has been returned for better address:

L. V. Cronican, 5922 Christian St., Philadelphia, Pa.

John J. W. Kenan, Prod. Mgr., Parish & Bingham Corp., Cleveland, Ohio.

Bolivar Reamy, 4052 Columbus Ave., Detroit, Mich.

E. Robinson, Wks. Mgr., International Time Recording Co. of New York, Endicott, N. Y.

Edward J. Russell, Hotel Strand, Chicago, Ill.

D. Thompson, Philadelphia Representative Landis Tool Co., Walton Hotel, Philadelphia, Pa.

The Secretary will appreciate any information which will enable him to get in touch with these members. Address Room 410, Munsey Building, Washington, D. C.

Long Range Small Arms Firing

PART IV

Machine Gun Dispersion

By

GLENN P. WILHELM
Member A. O. A.

THE war just ended has again demonstrated that decisive results can only be accomplished by the offensive. The offensive power of an army is measured solely by the willingness and capacity of its infantry to attack. It is the infantry, and the infantry only, that can win an attack, or make a successful defense.

Infantry is to-day as technical as some of the so-called technical branches. It includes the technique and tactics of many diverse branches. The machine gun alone probably requires as scientific training as field artillery. Technique is of nearly equal importance to tactics, and while tactics may take longer to acquire, mechanical perfection is certainly necessary, as the special infantry weapons are useless tactically unless served technically.

Modern infantry armament gives far greater destructive power to the individual. While the greatest element of success in battle, insofar as concerns the infantry, is the insistence upon training in rifle practice and the inculcation in the infantry soldier of the principle of relying on the rifle, the greatest obstacle to the successful offense to-day is the machine gun. It is chiefly responsible for the very extended formations in which infantry now attacks.

The importance of the machine gun is likely to increase. It is dangerous because of its great fire power and the element of surprise. Machine guns on the defensive paralyze the attack by inflicting annihilating losses in a minimum time by a sudden, overwhelming and unexpected fire. On the other hand, the machine gun is an element of attack and the most terrible arm of close fighting. It is the tooth of the attack.

Machine guns, however, are only useful when their tactical handling is thoroughly understood, and then their effect is more decisive than that of any other arm. This is possible on account of the characteristics of the weapon which has become the most deadly single article of armament, embodying as it does an unexpected, mobile, concentrated musketry fire upon a restricted front or point, the dispersion of which is long, very narrow, and of great density.*

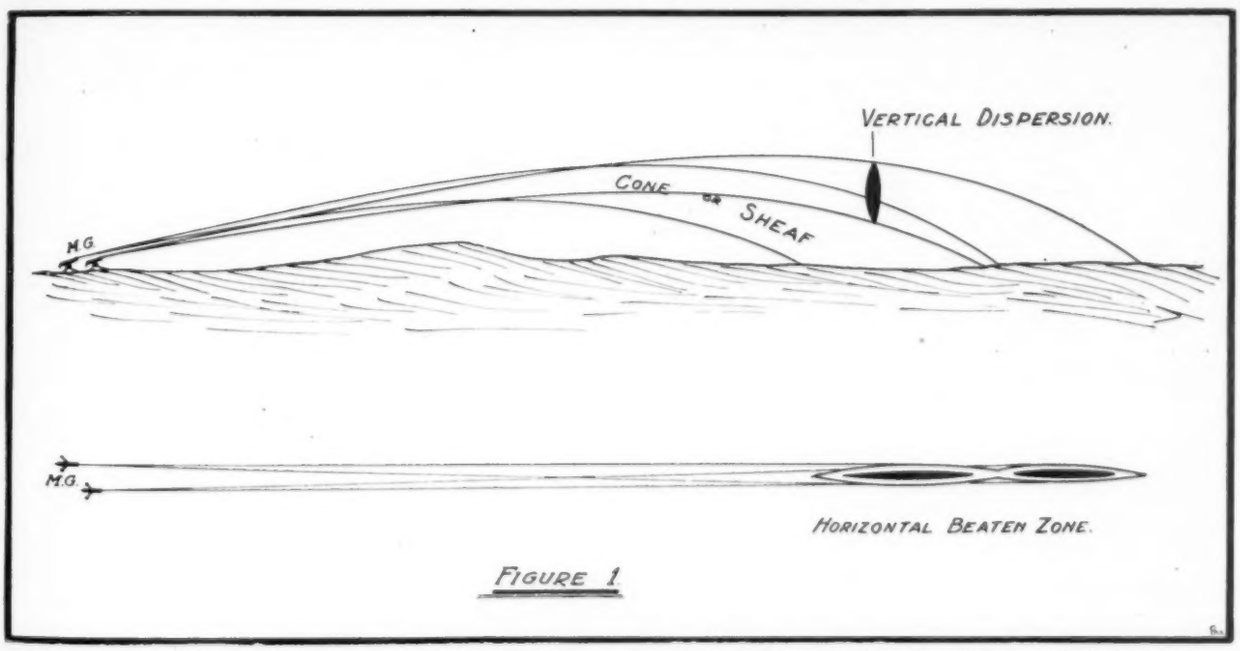


FIGURE 1

Machine Gun Fire Covering Target By Means of "Combined Sights," illustrating the Machine Gun "Sheaf" or "Cone" with Vertical and Horizontal Dispersion, including the "Beaten" Zone

It is the purpose of this article to show the exact nature of machine-gun dispersion, as it is the character of the dispersion of the bullets from the machine gun more than any other single factor which has made this weapon the most feared of all infantry arms.

The machine gun is the culmination of the age-old at-

*The author, in some of the foregoing paragraphs, acknowledges his indebtedness for the material to the Tactical Lessons of the Lewis Board and also to the writings of Captain Laffargue of the French Army.

tempt of man to design a weapon which would mechanically supply an unlimited amount of concentrated musketry fire. Very early in history the importance of an increased rate of fire was realized. The handicap of the early "hand gun" to the bow and arrow in this respect was one of the serious objections to the introduction of firearms for military purposes. Likewise, the great objection to the early rifle as a superior weapon to the muzzle-loading musket was the slowness and difficulty of loading. As late as 1808 the musket was capable of being fired three times as rapidly as the rifle.

The military value of the rifle during the Napoleonic Wars was so questionable that Napoleon withdrew the weapon from the French Army, substituting for it the old smooth bore. The rate of fire has always been an important characteristic of the application of fire power, as always in war skilled rifle fire by infantry has been found effective.

However, it is a far cry from the rate of fire for the old matchlocks of seven shots in eight hours at the battles of Kuisyingen in 1636 and Wittenmergen in 1638, to the rate of fire for the Browning machine gun of 250 rounds per minute of *aimed fire* in the Argonne Forest in 1918.

While magazine weapons and multi-barreled hand guns were of simultaneous origin with the most primitive match ignition, it has required centuries to achieve the modern Browning machine gun, capable of mechanically sustaining an effective, intensive rate of fire of over 500 shots per minute during a longer period than is required to wear out the barrel by erosion.

When a machine gun is fired automatically, the stream of bullets forms a cornucopia-shaped figure in the air, called the machine-gun sheaf or cone. (See Fig. No. 1.) The intersection of this sheaf with the ground surface is known as the beaten zone, although the words "sheaf" and "cone" are often applied to the beaten zone.

The machine-gun cone is often compared to the stream of water from the nozzle of a hose. While this comparison brings a clear picture to the mind of the layman, yet it is not as good a comparison as might first be thought, because it invariably produces in the popular mind, and to a certain extent this is also true in the Army, a false conception of machine-gun dispersion.

Insofar as the shape of the two figures are concerned, the comparison is satisfactory. However, the stream of water is made up of almost an infinite number of drops, giving it great density, while in the machine-gun sheaf, although the bullets are separated by an interval of time of only 1/10th of a second, the actual distance separating individual bullets is several hundred feet. As a consequence, the usual description of machine-gun fire, such as "The stream of machine-gun bullets swept the trenches from the right to left like a stream of water from a hose, etc.," is misleading, because, while a hose may be played over a given area by being swept from right to left so that the ground over which the stream passes will be entirely wet, when a single machine gun is traversed or swept on its mount in a horizontal circle little or no damage results, the area covered being so large compared to the number of bullets in the machine-gun sheaf that the fire cannot possibly be effective. Briefly, such fire from a machine gun lacks density.

Fig. No. 2 is a composite picture illustrating the machine-gun beaten zone in various forms as obtained on water. The upper illustration in the composite picture shows the dispersion of four Browning machine guns automatically firing service ammunition at a range of about 800 yards, the guns being in the rear of the photographer and firing down at an angle of about five degrees, thus causing the beaten zone to be foreshortened. The middle left illustration in the composite picture is similar to the illustration above, except that two guns only are being used and the range is about 1,200 yards, the guns firing down at an angle of about three degrees. These two illustrations show clearly the density and extreme narrowness of the beaten zone. The middle right illustration and the lower illustration in the composite picture show the dispersion of four Browning machine guns located on a level with the lake at a range of about 1,100 yards to the left in prolongation of the line of splashes. The middle right illustration shows the beaten zone of two guns coinciding, the other two guns being separated and slightly to the right, while the lower illustration shows the beaten zone of all four guns overlapping, making one wide beaten zone.

The machine-gun cone of dispersion must be considered in two ways:

First, the dimensions of the dispersion in a vertical plane.
Second, the dimensions in a horizontal plane.

For instance, machine-gun dispersion at a range of 1,000 yards consists of two parts. The vertical dispersion is made up of the intersection of a vertical plane with the machine-gun sheaf or cone at a distance of 1,000 yards from the gun. Likewise, at a range of 1,000 yards there will result the machine-gun beaten zone, which is the pattern described by the individual shots of the machine-gun bullets on the surface of the ground. The area of this pattern is the intersection of the machine-gun cone with the surface of the ground.

Therefore the dimensions of the vertical dispersion consists of the width and height, while the dimensions of the horizontal dispersion, or beaten zone, consist of the horizontal width and length.

Machine-gun tables of fire by which the fire power of the machine gun is applied effectively in battle, require figures showing the dimensions of both vertical and horizontal machine-gun dispersion. The purpose of the vertical dispersion table is to avoid our machine-gun fire striking our own troops, over whose head machine-gun fire is often directed on the enemy target. However, in order to effectively cover the enemy target it is necessary to know the limits of the horizontal beaten zone to insure that the pattern may inevitably include the enemy target.

The purpose of machine-gun dispersion tables, therefore, is, briefly, to hit (the enemy) and yet not to hit (our own troops).

Fire tables, giving the dimensions of horizontal machine-gun dispersion, which are necessary in order to make hits on enemy targets, are always based on averages, because it is the average size of the beaten zone which must be taken into consideration. On the other hand, the table of vertical machine-gun dispersion, which is necessary to avoid endangering the advancing infantry by overhead fire, must be based on extremes and not on averages, because it is the very lowest shot from the machine-gun burst which may strike the friendly troops, and, naturally, they are not interested in the fact that the average bullet from a machine-gun burst may not cause a casualty, if at the same time casualties are being caused by shots which do not conform to the law of averages.

Vertical machine-gun dispersion is necessary to a certain extent in order to fire effectively at anti-aircraft targets, such as airplanes, balloons, etc.

Figs. No. 3A, No. 3B, No. 3C, No. 3D, and No. 3E give characteristic beaten zones from one Browning machine gun with service ammunition at ranges of 1,000 meters (1,100 yards), 1,500 meters (1,650 yards), 2,000 meters (2,200 yards), 2,500 meters (2,750 yards), and 3,000 meters (3,300 yards), respectively.

Kinds of Machine-Gun Dispersion

Machine-gun dispersion is made up of the following classes:

Horizontal Dispersion for One Machine Gun at all Ranges—

No. 1. Average length and width of the dispersion of one machine gun.

No. 2. Average length and width of the total area covered by the dispersion of one gun firing at different times with a varying center of impact, assuming a constant angle of departure.

more than one gun are probably insurmountable, except under the ideal conditions which it will be possible to obtain on special experimental ranges.

It has also been found that the measurement of the machine-gun dispersion of one gun at a time, but involving the firing of several hundred guns, is more reliable than the firing of a smaller number of guns simultaneously, because of the greater accuracy possible in observations of the dispersion of one gun at a time. Moreover, it is usually possible to obtain a greater amount of data by using a larger number of guns, one at a time. This could also be done

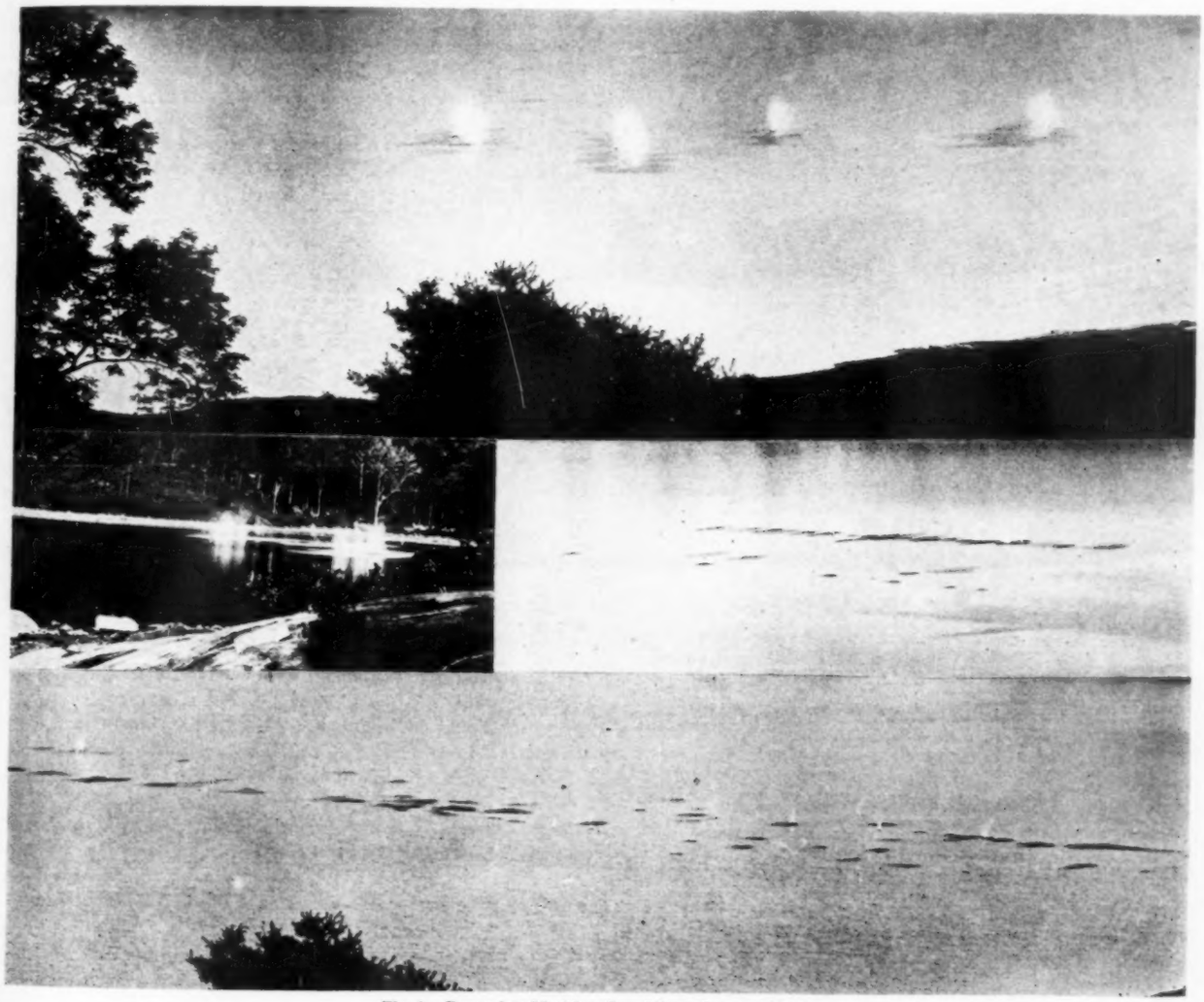


Fig. 2. Browning Machine Gun Dispersion on Water

Horizontal Dispersion for More Than One Machine Gun Firing at all Ranges—

No. 3. Average length and width of the dispersion when guns are fired simultaneously.

No. 4. Average length and width of the total area covered by the dispersion of all guns when fired simultaneously but the firings taking place at different times, assuming constant angles of departure.

Vertical Dispersions Obtained with Horizontal Dispersions No. 1, No. 2, No. 3 and No. 4

Measurement of Machine-Gun Dispersion. The accurate measurement of machine-gun dispersion is a considerable problem. It is exceedingly difficult to determine the data for one gun at a time. Therefore the difficulties in firing by firing more than one gun, but the point is that the firing of 10 guns simultaneously would not give as valuable information as the firing of 100 guns, one at a time.

When more than one gun is fired simultaneously, unless each gun individually is laid with the same center of impact by observation, no two beaten zones will coincide, because the direction and elevation of the stream of bullets from each gun are actually different, even with the greatest care and the most precise of service instruments. Moreover, even if a paper screen were used in front of the gun, in order to maintain the same direction and equal elevations on all of the ten guns, it would be impossible to keep them at a constant angle.

Combined Machine-Gun Dispersion (simultaneous firing

of any predetermined unit consisting of more than one gun) can be obtained as follows:

1st—Determine the average size of normal horizontal machine-gun dispersion of one gun at all ranges by taking the mean of a large number of individual guns.

2nd—By means of a paper screen (1,000-inch range will do), determine average actual lines of departure of bullets from each gun by the simultaneous firing of more than one gun, all being laid with the same gun elevation and deflection.

3rd—Plot the centers of impact of burst from each gun, using actual elevation and direction of line of departure (not necessarily gun elevation and deflection).

4th—Plot combined area of dispersion by using average area of dispersion for each gun and each individual center of impact.

The reason why the above method is probably the most practical one to determine combined dispersion can be seen from the following discussion of the various factors affecting dispersion:

obtained with several guns firing simultaneously. However, in the latter case the unknown line of departure and deflection has the effect of giving each gun a different center of impact, so that the combined area of the dispersion of all guns is much greater than for any individual gun, although each gun has approximately the same dispersion.

Three Factors Affect Combined Machine-Gun Dispersion. The ammunition dispersion is practically constant for all guns. However, the gun vibration depends upon a number of factors, such as set-up, etc. Under similar conditions the gun vibration will also be constant. Therefore of the three factors affecting the combined machine-gun dispersion, viz., the unknown line of departure and direction, gun vibration, and ammunition dispersion, two are constant, leaving the unknown line of departure and direction to be the chief cause of the increased size of the combined dispersion.

Method of Determining Combined Dispersion. Stating it another way, ten machine guns fired simultaneously with equal angles of departure (which can never be obtained

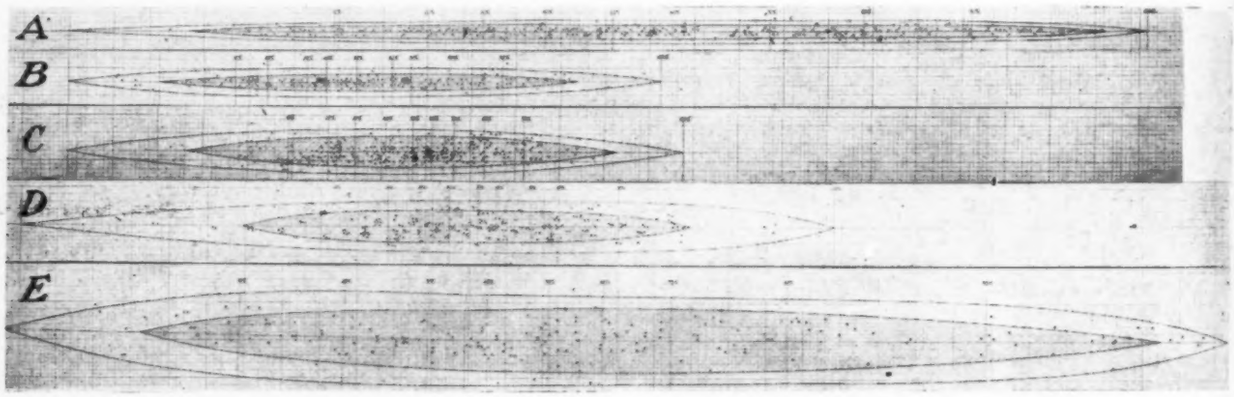


Fig. 3. Browning Machine Gun Dispersion with Service Ammunition at Ranges of 1000, 1500, 2000, 2500 and 3000 Meters

Two Factors Governing Possibility of Hitting a Target. There are two factors which chiefly affect the probability of hitting a target at a known range, excluding dispersion. The first is the unknown line of direction and elevation. The second is the unknown effect of meterological conditions on the flight of the bullets. This makes it impossible to determine where the center of impact will be located, because in firing with service instruments under service conditions the line of elevation and direction of the bullets is subject to considerable error, and with the best of tables for the correction of weather conditions there still remains an appreciable error.

This is very well illustrated in Fig. No. 2, in which, although the guns were laid by observation, it was impossible to get the centers of impact at exactly the same range or to get the beaten zones parallel to each other with an equal interval between zones.

Two Factors Governing Size of Dispersion. The size of the dispersion for one machine gun firing at one time is also affected by two factors, the first of which is the gun vibration set up by the combined action of the movement of the barrel in its seat and the play between the gun and tripod, including the springing of the tripod. The second factor is the ammunition dispersion, i. e., the inevitable variation in the flight of individual bullets due to imperfect form, velocity, etc., although all bullets may leave the muzzle with exactly the same line of departure.

The weather has little or no effect upon the size of machine-gun dispersion for one gun or upon the dispersion

with the service clinometer) will have their shortest and longest shots at approximately the same range, as will also be their center of impact, because, as previously stated, the weather and other conditions affect all guns the same. Inasmuch as the factor which controls the total area and depth over which the beaten zones have varying centers of impact is directly controlled by the variation in the line of departures; therefore the total area covered by the ten guns firing simultaneously can be determined by taking each gun individually and measuring the variation obtained in the line of departure, and combining the average area covered by one gun at this range.

Relation Between Dispersion and Size of Burst. Regarding the size of machine-gun dispersion with varying size of burst, the following has been found to be approximately true. The total number of shots fired will cover the same area at a given range, regardless of the size of burst, providing single shots are not fired, as in this case there is little or no gun vibration. Therefore ten bursts of 25 rounds each would cover the same area as 25 bursts of 10 rounds each or one burst of 250 rounds. Also 10 bursts of 25 rounds will not cover an area ten times larger than one burst of 25 rounds. In fact, the area is but slightly greater.

For example, Figs. No. 4A, 4B, 4C, 4D and 4E show Browning Machine-Gun dispersion with service ammunition at a range of 1,000 meters (1,100 yards), 1,500 meters (1,650 yards), 2,000 meters (2,200 yards), 2,500 meters (2,750 yards), and 3,000 meters (3,300 yards), respectively. The beaten zones on the right are for all practical purposes

of the same dimensions as those on the left, although those on the left were fired with bursts of approximately 200 rounds, while those on the right contained approximately 1,000 rounds (20 bursts of 50 shots) each. The beaten zones on the right are a mean of the beaten zones of both the Vickers and Browning machine guns firing service ammunition as determined on the beach in France, while those on the left were determined for the Browning machine gun only on the beach at Daytona, Fla.

Characteristics of the Horizontal Machine-Gun Dispersion of One Gun (Service Ammunition).

A study of effective beaten zone horizontal machine-gun dispersion of one gun (automatic fire) at all ranges plotted exactly as the shots fall shows that the density of the hits per unit area around the center of impact is but little, if

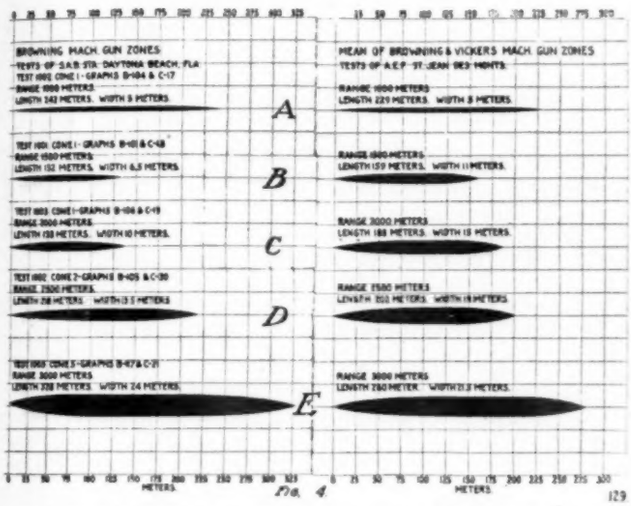


Fig. 4

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Comparison of Browning Machine Gun Dispersion, Florida Firings, with Mean of Browning and Vickers Machine Gun Dispersion As Determined by A. E. F.

any, greater than it is near the limits of the dispersion in both width and length, with the exception of stray shots not exceeding about 10 per cent of the total number of shots in the burst.

In other words, as far as one gun is concerned a target will receive as many hits per unit area at the limits of the dispersion (omitting strays) as it would receive at the center of impact.

For example, the beaten zones shown in Fig. No. 3 contain the individual shots, the cross-hatched section showing 85 per cent of all the shots, which is considered to be the effective portion of the zone. Each zone has been divided up by vertical lines marking off areas which contain 10 per cent of the total number of hits.

Effective Length. Dispersion decreases in length as the range increases up to a range of about 2,000 yards, after which it increases in length. This is because up to a range of 2,000 yards the "gun error" is considerably larger than the "ammunition error" and the main factor in the "cone of dispersion" (cornucopia shape of the machine-gun sheaf in air) is due to gun and tripod vibration. This cone, if cut by a plane, such as horizontal ground, at increasing ranges, will result in the intersection decreasing in length as the angle of fall increases.

However, at ranges beyond 2,000 yards the individual bullets of the sheaf are each seeking out paths of their own, due to variations from various causes, so that the increase in the angle of fall will not compensate for the increase in the vertical dispersion and consequent increase in horizontal.

For example, Fig. No. 3 and Fig. No. 4 show the beaten zone decreasing in length as the range increases up to about 2,000 yards, after which it increases. It is quite apparent in Fig. No. 3D and No. 3E that the individual bullets of the beaten zone are becoming widely separated.

Effective Width. On the other hand, the width of the horizontal dispersion will increase proportionally to the range, the width always being greater than the relation in the range, i. e., the width at 2,000 yards will be more than four times as great as at 500 yards and over twice as great as at 1,000 yards.

Figs. 3-4 show this increase in width as range increases.

Developments in Artillery Motor Carriages

In co-operation with the Ordnance Department, United States Army, the Holt Manufacturing Company at their plant at Stockton, Cal., have just completed two new types of motor gun carriages of the self-propelled "Caterpillar" design. One of these new motor carriages mounts interchangeably either the 75 mm. gun or the 105 mm. howitzer Models 1920, while the larger type carriage mounts interchangeably either the 155 mm. gun or 8-inch howitzer, Models 1920. Two each of these new types of motor carriages have been manufactured and are now en route to the Aberdeen Proving Ground, Maryland, for final proof-firing and maneuvering tests.

The successful completion and excellent features of these motor carriages exemplifies the rapid strides which have been made in the design and development of this new type of artillery materiel, and at the same time illustrates the splendid results obtainable by close co-operation and personal contact of the Army with civilian industry. Although Mr. Pliny E. Holt, Vice President of the Company, who was with the Ordnance Department during the war, was directly in charge of the work, Mr. T. S. Baxter, President of the Holt Manufacturing Company, as well as other officials of the Company, took a personal interest, all of which materially added to the success of this important development work.

The 75 mm. gun—105 mm. howitzer motor carriage Model 1921—has a total weight of 13,000 pounds and a maximum speed of 30 miles per hour. This is the highest speed for a "Caterpillar" track vehicle which has ever been obtained and the attainment of this remarkable speed establishes a new high record in "Caterpillar" design. These two motor carriages were successfully proof-fired at Fort Winfield Scott, Cal., during the latter part of April and exhibited a very high degree of stability during the firing tests. This carriage is equipped with a 75 horsepower 8-cylinder engine designed and built by the Holt Manufacturing Company.

Upon completion of the firing tests the power plant of this type motor carriage was completely waterproofed and both carriages thoroughly tested completely submerged except for the driver's head and a breather pipe leading to the engine. Briefly, this motor carriage possesses stability during firing; a normal speed of 15 miles per hour for continuous running with a maximum of 30 miles per hour; and the ability to cross small streams, such as would be encountered in maneuvering across country off the roads.

The 155 mm. Gun—8-inch Howitzer Motor Carriage, Model 1921, complete with the gun or howitzer, will weigh approximately 22 tons and have a maximum speed of 15 miles per hour on good roads. This carriage is equipped with a 250 horsepower 6-cylinder Sterling engine which provides sufficient power to enable the carriage to negotiate difficult grades in cross country work and to attain the high speed of 15 miles per hour on the road.

The important features of the design of this powerful motor carriage are quite interesting. The 5 degree traverse of the gun on the carriage either side of center is supplemented by easily operated hand traversing cranks which permit this carriage to deliver all around fire. The axis of the gun is only 64 inches above the ground allowing the cannoneers while loading and laying the gun to stand on the ground, which eliminates the necessity for a raised loading platform. Outriggers provided on the rear of this carriage to insure stability during firing are quickly dropped into place upon reaching the firing point, so that there is practically no delay in opening fire with this type of carriage upon reaching the gun position.

Hoke Gages

By

EARLE BUCKINGHAM

Member A. O. A.

ANY one who is at all familiar with the production of munitions in large quantities fully realizes the great importance of accurate gages, and also the large number of these gages which are required for production and inspection.

Where limit gages are employed, the product will always follow these gages. Thus the setting of a machine or tool is not altered as long as the product satisfies these gages. These gages wear with use, and the direction of wear is the same on both tool and gage. Thus a reamer and the plug gage which is used to measure the reamed hole wear smaller with use, while a box-tool or die and the ring or snap gage used to test the results wear larger. If this wear were permitted to go on indefinitely, the sizes of the product would soon be beyond the limits which were required to produce satisfactory results. Therefore it is necessary to test the gages frequently to insure that the required degree of accuracy is maintained.

The original method of testing these gages was to provide a hardened test piece which would fit each size of gage. These test pieces are very expensive, as they must be made very accurately. Furthermore, the number required is almost infinite, as the least variation in the size of a gage required a separate test piece.

Fig. 1

Several years ago a Swedish inventor, Mr. C. E. Johansson, brought out a series of size blocks of such high accuracy, and finish, that with a series of 81 blocks, any dimension from .200″ to over 10.000″ could be obtained in increments of .0001″. A set of these blocks would more than take the place of the large number of individual size blocks formerly required to test the inspection and working gages.

These blocks were produced in Sweden, and the method of their manufacture has been kept a secret. When the war broke out, only a relatively small number of sets of these blocks were in use in this country, and it was impossible to procure as many as could be used to advantage. For example, it took the Ordnance Department several months to obtain about a dozen sets, and even then they had to commandeer several sets which were consigned to private manufacturers.

About this time Mr. W. E. Hoke, of St. Louis, came to the Bureau of Standards with an idea which he believed would enable these blocks to be made. Permission was readily granted him to use the shops at the Bureau to carry through an experimental batch. Mr. Hoke soon demonstrated that he was working along correct lines, and the Ordnance Department, which quickly realized the importance of his invention, allocated a hundred thousand dollars to the Bureau of Standards to enable them to proceed with the manufacture of several hundred sets of these blocks. Mr. Hoke was commissioned a Major in the Ordnance Department and placed in charge of the manufacture of these blocks.

It soon became apparent that the blocks produced by Major Hoke's process were even superior in flatness, parallelism, and size to the imported Swedish blocks. Here again was another instance of where, during the stress of war, this country became independent of a foreign source of supply for vitally needed material.

After the war the commercial rights to Major Hoke's process were acquired from him by the Pratt and Whitney Company, who have now placed these gages on the market.

It is of interest to consider briefly some of the manufacturing problems involved in the production of these gages. Contrary to the Swedish practice, this process is not a secret and visitors are shown the departments engaged in this work as freely as they are shown the other manufacturing departments of the plant.

Before describing how these blocks are made, a few of the requirements which gages of this kind must fulfill will be summarized:

First. The two gaging surfaces must be true planes so that the blocks will adhere firmly to each other when wrung together.

Second. The two gaging surfaces must be parallel to each other.

Third. The length of the gage or the distance from one gaging surface to the other must be held very closely to a predetermined size. Several blocks are wrung together to make various sizes. In order that the length of the assembled blocks does not vary appreciably from the desired dimension, the errors in the individual blocks must be kept to a minimum.

Fourth. The gage blocks of a set must differ in size or length by such increments as make it possible to obtain any dimension within the extreme range covered by the set of blocks.

Fifth. The finished gage must possess the quality of

permanence or stability so that it will retain its original accuracy of form and size. This does not mean that the sizes of the gages will not change with differences of temperature. It does mean, however, that when the gage is brought to the standard temperature (68° F.) it will always have the same length. The steel used in making these gages must resist corrosion as much as possible and must be heat-treated to produce hard gaging surfaces that will not scratch readily.

In Fig. 1 is shown a set of these gages which covers a range of from two-tenths of an inch to over ten inches by increments of one tenth of a thousandth part of an inch.

The selection of the steel which is used in these gages is very important. Each bar of steel is subjected to a chemical and microscopic analysis before it is used. The roughing operations on these gages offer nothing out of the ordinary. Any method of cutting up the blocks to their rough form would be satisfactory.

The heat-treating operations are among the most essential and also most critical processes in the manufacture of these blocks. Several successive treatments are given, each of which must be controlled within a very narrow range.

After heat-treating and rough grinding, the blocks are carefully inspected for hardness and cracks. They are then given an accelerated seasoning treatment and stored for several months for further seasoning.

The final lapping operations are the most interesting. This lapping is entirely mechanical. A battery of lapping machines is shown in Fig. 2. The essential parts of these machines consist of two flat laps of circular form and a steel plate, or spider, between them. The lower lap is attached to the base of the machine and the upper lap is attached to an arm by a connection which permits the lap to move freely in any direction, but not to revolve. This arm is pivoted at one end so that the upper lap can be swung to one side, as shown in Fig. 3, to expose the work. When a machine is in use, one lap is above the other, as shown in Fig. 4, and the gage blocks are between them so that the upper and lower surfaces of the blocks are lapped simultaneously.

In operation, the upper and lower laps remain stationary, while the spider receives a planetary motion which brings each block into contact with the entire surface of each lap. This motion of the spider is derived from three cranks which are attached to the upper ends of vertical shafts. At the end of each crank there is a pinion which is rigidly secured to the crank so that it cannot revolve about its own axis. These three pinions mesh with the external gear which is attached to the spider. The three cranks rotate in unison, and as they revolve the spider is carried around between the pinions. Thus the spider is given a combined eccentric and rolling motion which carries the blocks inward and outward across the face of the laps together with an advancing motion. The gearing is so chosen that the cranks make about 300,000 revolutions before a given block in the spider will again follow the same path relative to the faces of the laps. The wear on the laps is also further distributed by reason of the fact that the blocks themselves revolve with more or less irregularity at first and then quite uniformly and in the same direction as the

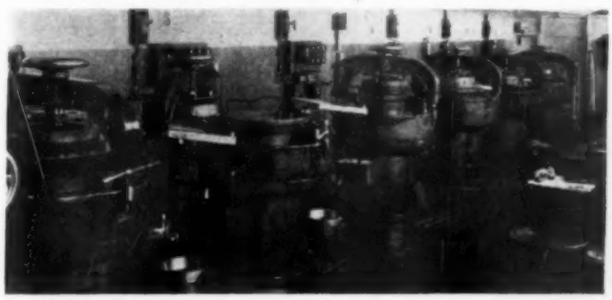


Fig. 2

surfaces become true. When lapping comparatively long blocks, considerable pressure is applied to the upper lap to prevent the blocks from tipping.

The lapping process must be carried on so that the gaging surfaces gradually approach flatness and parallelism as the gage is being reduced to the correct size. While it would be relatively simple to lap the upper and lower ends until they are flat, it is very essential to so handle the work that both flat and parallel surfaces are secured either before or when the gage is finished to the required dimension. When the blocks are first placed in the machine, there are sure to be very slight irregularities in regard to the heights of different blocks, as well as slight errors in the flatness and parallelism of their surfaces. As the upper lap is free to adjust itself, it naturally rests upon the three highest points or surfaces on the circular row of blocks, and as the blocks are carried around between the laps, these high areas are soon enlarged. Now if the lapping were continued without changing the blocks, the surfaces might be finished flat, but the plane of the upper surfaces would not be paral-

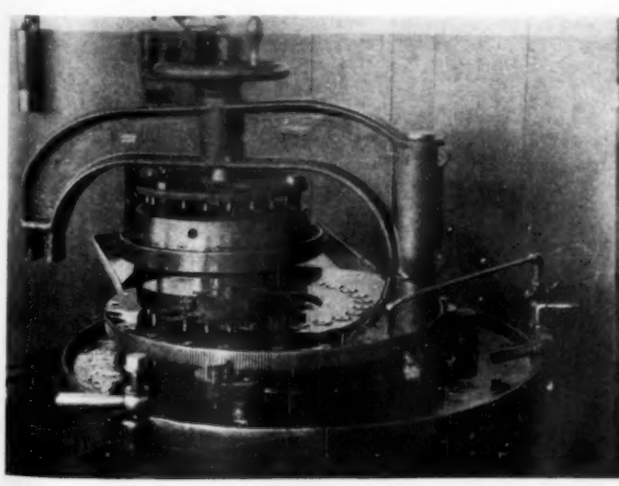


Fig. 3

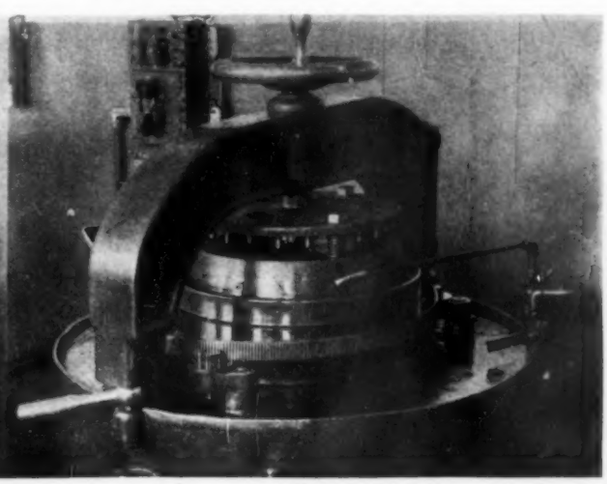


Fig. 4

lel to the plane of the lower surfaces, assuming that there was some slight variation in height to begin with, as would ordinarily be the case. The problem then is to lap all the blocks flat and parallel while they are being reduced to the same length or height. This is accomplished by changing the relative positions of the blocks at intervals during the lapping period.

The transposition of the blocks is a very essential part of the work, and if this were not done, it would be impossible to lap the opposite surfaces of the blocks flat and parallel at the same time. Whenever a set of rough blocks is placed between the laps, the upper lap is sure to rest upon the three highest points or areas, and if the upper lap were in an inclined position to begin with, it would ordinarily tend to remain out of parallel with the lower lap. To avoid this lack of parallelism, the minute errors in heights of different blocks are gradually eliminated by the following method: After the machine has made a certain number of turns, the upper lap is swung out of the way and every other block is moved 180 degrees, or to a position diametrically opposite. As the result of this shifting of the blocks, either the highest one in the set, or the one next to it, is moved across the plate, and owing to these changes of position, height errors are reduced about one-half. Sometimes the blocks are shifted only 90 degrees, thus further dividing and reducing the error, and by repeatedly changing positions, the upper surfaces are finally brought into parallelism with the lower surfaces.

The final testing of the gages for flatness, parallelism and size is done by optical methods, which have been described quite fully in various recent technical publications. Needless to say, it must be conducted with the utmost care.

75-mm. Pack Howitzer *vs.* 2.95-inch V. M. Mountain Gun

By

O. L. BEARDSLEY

Member A. O. A.

PACK or mountain artillery involves such guns and carriages, together with their accompanying equipment, as can be readily disassembled and packed on the backs of animals for transportation through mountainous country and into positions inaccessible to horse-drawn or motorized artillery. As mules are preferable to horses for the carrying of such burdens, they are always used when available.

In the consideration of the design of a piece of pack artillery the question of packing is of prime importance, as no piece, however powerful, which was not readily adaptable to packing could successfully be used. Therefore in such designs the pack load is considered as a unit and the important points to be observed in the loads are minimum weight, minimum length and minimum number.

A description of the pack harness now in use in our army will not be given here except to say that the principal component is the Aparejo, which is a large double-walled leather saddle stuffed with hay or grass, being a development of an early type of Mexican pack saddle. The Aparejo supports suitably designed metal pack frames for accommodating the pack loads which are finally secured to the mule with broad fabric cinchas.

The Westervelt Board in its conferences at the close of the war took up the subject of pack artillery and laid down specifications for an ideal gun and carriage as follows:

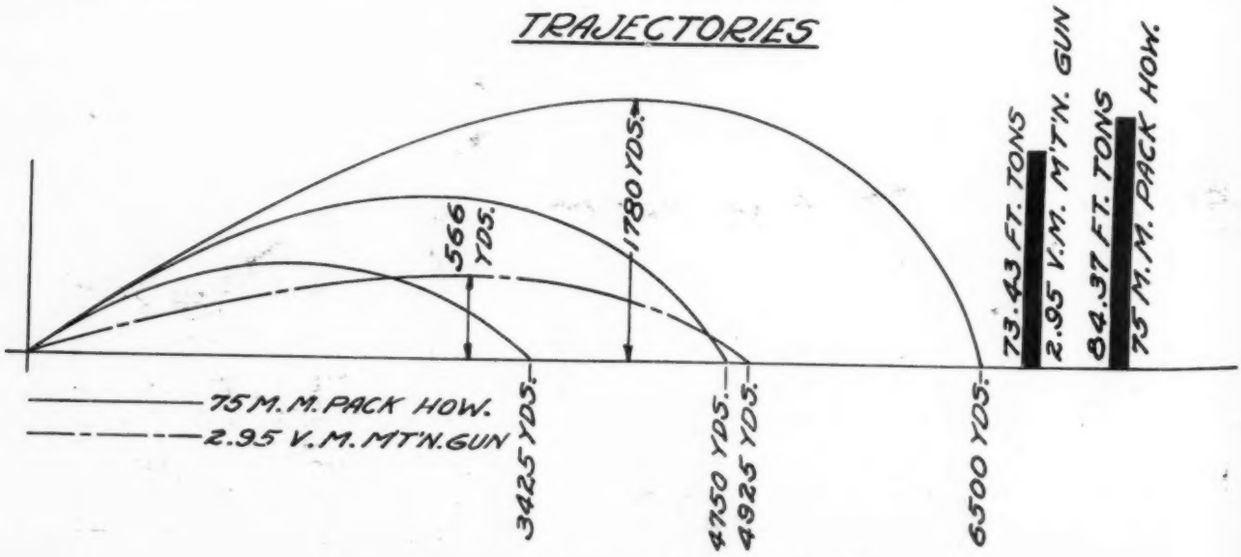


Fig. 1. Diagram of Comparative Ranges, and Muzzle Energies in Foot-tons

Caliber of about 3 inches; to use division gun projectiles if possible; elevation not less than 45 degrees; range not less than 5,000 yards; pack loads not to exceed 225 pounds, exclusive of pack harness.

Following these specifications a design was laid down and two pilot carriages built which at present are undergoing proof test at the Aberdeen Proving Ground. This carriage is known as the 75 mm. Pack Howitzer Carriage, Model of 1920, a description of which will be given in this article.

The great powers have all produced varied types of pack artillery; however, a discussion of these types will not be entered into here, but only a comparison drawn between the 2.95 in. V. M. Mountain Gun now in use and the 75 mm. Pack Howitzer, Model of 1920.

The 2.95-inch V. M. Mountain Gun

This carriage, designed by the Vickers-Maxim Company, was in use in this country during the Spanish-American War. While the carriage possesses many desirable features, it does not possess others considered essential in modern carriages. The bore is 2.95 inches in diameter, and it

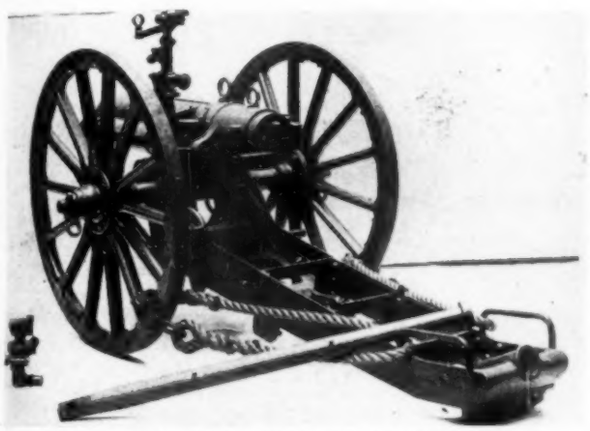


Fig. 2. 2.95-inch Vickers-Maxim Mountain Gun Carriage

fires the 12.5-pound shell and shrapnel with a muzzle velocity of 920 feet per second, from which a maximum range of 4,925 yards is obtained at the elevation of 27 degrees permitted by the carriage. Only one powder charge is provided. The vertical arc of fire is from 10 degrees depression to 27 degrees elevation. No means of traversing is provided as traverse is wholly accomplished by shifting the trail, prohibiting a quick, close adjustment in azimuth. The gun is provided with an interrupted screw type breech block which automatically cocks the firing mechanism when the block is closed, the firing pin being tripped with a lanyard attached to the trigger on the left side of the breech. The cradle is a bronze casting containing a recoil cylinder on each side, and having a hole through the center through which the gun is inserted and providing a slide for the gun during recoil.

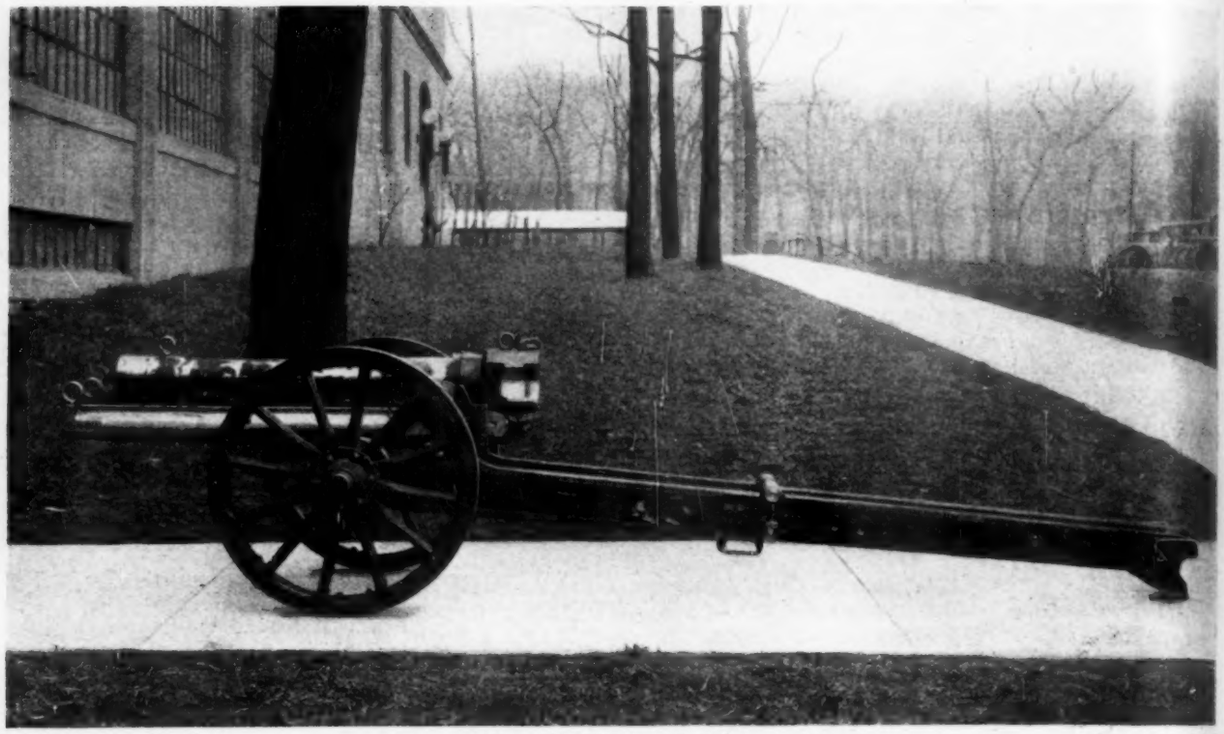
The gun is secured in position by making connection with the two piston rods, this operation being accomplished by means of interrupted screw threads on the ends of the rods. The recoil mechanism is of the hydro-spring type in which oil is forced past simple piston heads by way of slots of varying width in the bronze liners surrounding the pistons; the pull on the rods being equalized by a connecting passageway at the rear ends of the cylinders. The gun is returned to battery by means of helical flat springs working against the piston heads inside the cylinders. The length of recoil is 14 inches, and is constant for all elevations. As this length of recoil is sufficient to absorb only a portion of the energy of recoil, the carriage is not stable at any angle of elevation, therefore it is allowed to roll backward on its wheels, there being only a short spade at the end of the trail which serves as a scraper to check the backward movement. The trail is composed of two parallel vertical plates tied across at intervals with single plate transoms. The elevating mechanism is of the worm and rack type, the worm being rotated by means of a single pair of bevel gears and a handwheel on the left side of the carriage. The tipping parts being somewhat out of balance, there exists a small breech preponderance which is partially equalized by the action of two helical tension springs which exert an upward pull on the elevating arc. The elevating mechanism remains intact with the trail when packed. Standard 36-inch artillery wheels with steel tires are used. The Sight, Model 1912, and the Panoramic Sight, Model 1915, are employed on this carriage, being mounted together on the left side of the cradle. No shield is provided. The pack loads for this carriage are four in number, and are the gun, cradle, trail, and wheels and axle. These loads are not all well adapted to packing, but all are within the later prescribed weight limit of 225 pounds, except that of the gun which weighs 236 pounds. However, this being a short load, little difficulty is experienced in packing it.

The power of the weapon is somewhat less than desired, and due to the limited elevation permitted, the range is shorter than necessary. As no accurate movement can be obtained in azimuth, the piece cannot be aimed with precision and rapidity; and the carriage being unstable at all elevations, it must necessarily be re-laid after each round. The sights must be removed from the carriage before firing. However, due to its rugged and compact construction, the carriage may be handled and fired with small probability of damage or of being put out of action, and it has given good service. The complete carriage in the firing position weighs approximately 830 pounds.

The 75 mm. Pack Howitzer Carriage, Model 1920

As was previously stated this carriage was an attempt to meet the specifications of the Westervelt Board. Two designs were carried on simultaneously, the carriages being identical excepting the method of assembling the axle. The two guns have the same ballistics, but No. 1 gun has a side sliding breech block, while No. 2 gun has the screw swing block. Both guns fire the 75 mm. 15-lb. (Division Gun) projectiles with a maximum muzzle velocity of 900 feet per second from which a maximum range of 6,500 yards is obtained. As zone fire is to be employed with these carriages, two reduced powder charges are provided giving maximum ranges of 3,425 yards and 4,750 yards, respectively. The vertical arc of fire is from 5 degrees depression to 45 degrees elevation and a horizontal arc of 5 degrees. No. 1 gun has a simple spring and hammer firing mechanism operated with a short lanyard, while No. 2 gun is fitted with a firing mechanism substantially the same in operation as described above for the 2.95-inch V. M. Mountain Gun.

The carriages are provided with hydro-pneumatic recoil mechanisms of the St. Chamond type, permitting variable lengths of recoil from 28 inches at the lower angles of elevation to 18 inches at the higher angles, thus enabling the gun to be located 24 inches from the ground and yet clear the ground when firing at extreme elevation. The action of changing the length of recoil is automatic. Inas-



75-mm. Howitzer, Model 1920. Left side zero elevation

much as this type of recoil mechanism has been described in detail in a previous issue, a further description will not be given here.

The elevating mechanism consists of a spur rack in mesh with a pinion; the pinion being rotated by means of a worm wheel and worm, power being applied to the worm through a pair of bevel gears and a handwheel on either side of the carriage. To increase the ground clearance at maximum elevation the trunnions are located toward the rear end of the cradle, causing a muzzle preponderance in the tipping parts. As this would require an effort at the elevating handwheel greatly in excess of that desired, two spiral equilibrator springs were attached to the elevating pinion shaft, one on each end, whose function is to counteract the unbalanced gravity moment of the tipping parts. The entire elevating mechanism remains with the trail when packed.

The trail is in two sections fastened together with a hinge joint permitting the trail to be folded to reduce its length when packed. The two sections are approximately of the same length, and are formed of two parallel vertical plates flanged outward on both the upper and lower edges and tied across with transoms. The rear section is provided with a spade at its lower end sufficient in size to withstand the ground reaction during recoil.

The cradle is a high grade steel forging, and contains the recoil mechanism. It is trunnioned at the rear end and is pillowed in bearings on the forward end of the trail and secured in place with quick detachable locks. The cradle engages the elevating arc by means of lugs, when in place on the trail, and without the use of pins or other fastenings. The two carriages are of the axle traverse type; traverse being accomplished by means of a square threaded handwheel surrounding and engaging similar threads on the axle. The handwheel remains on the axle at all times, and when the axle is assembled in the trail, the handwheel engages surfaces in the trail enabling the carriage to be moved in azimuth by turning the handwheel in either direction. The standard 29-inch artillery wheels with steel tires are used on these carriages.

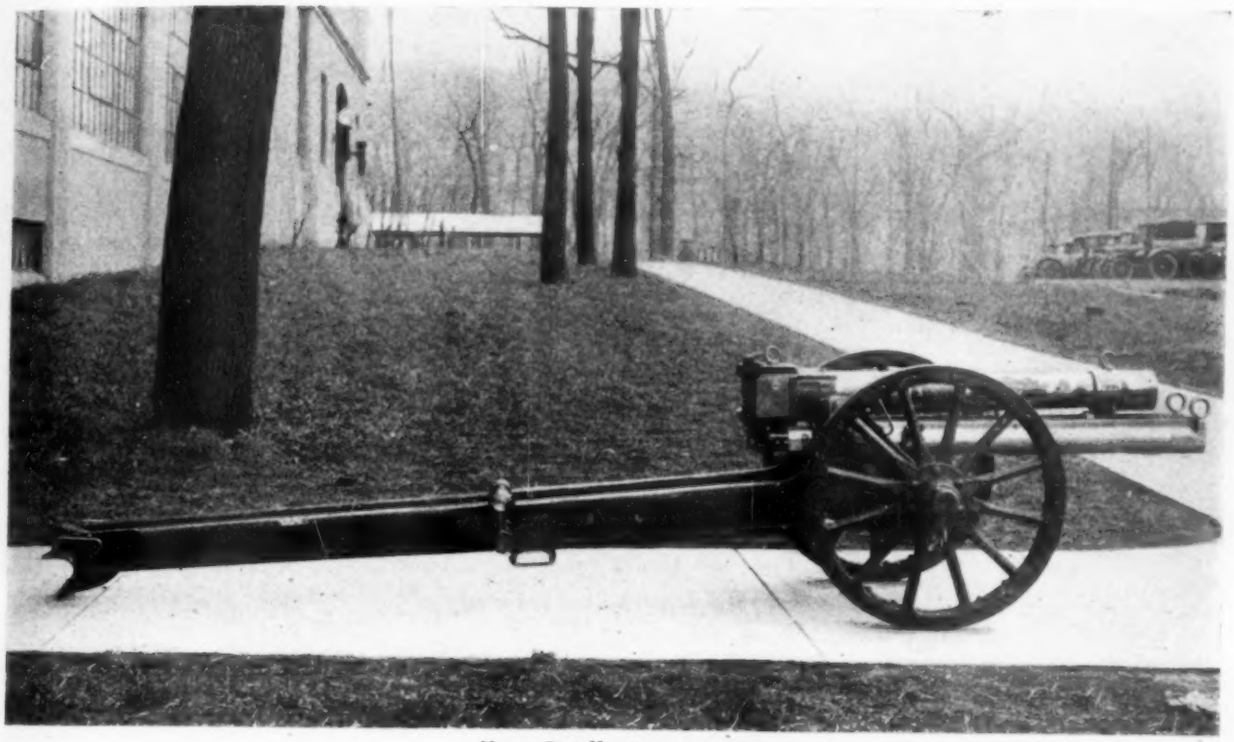
A special design of sight having a range drum graduated in three zones, and a Panoramic Sight are mounted on the left trunnion, while a range quadrant is mounted on the right trunnion. As it was the opinion of the Board that a shield was unnecessary, none was provided. The carriage packs in four loads of similar units to that of the 2.95" gun, and all have so far proven reasonably satisfactory, the load weights falling within the prescribed limit of 225 lbs., with the exception of the cradle which weighs 233 lbs.

The carriage can be disassembled for packing or assembled for firing in less than one minute. The weight of No. 1 gun and carriage in the firing position is 850 lbs and of No. 2 gun and carriage 820 lbs.

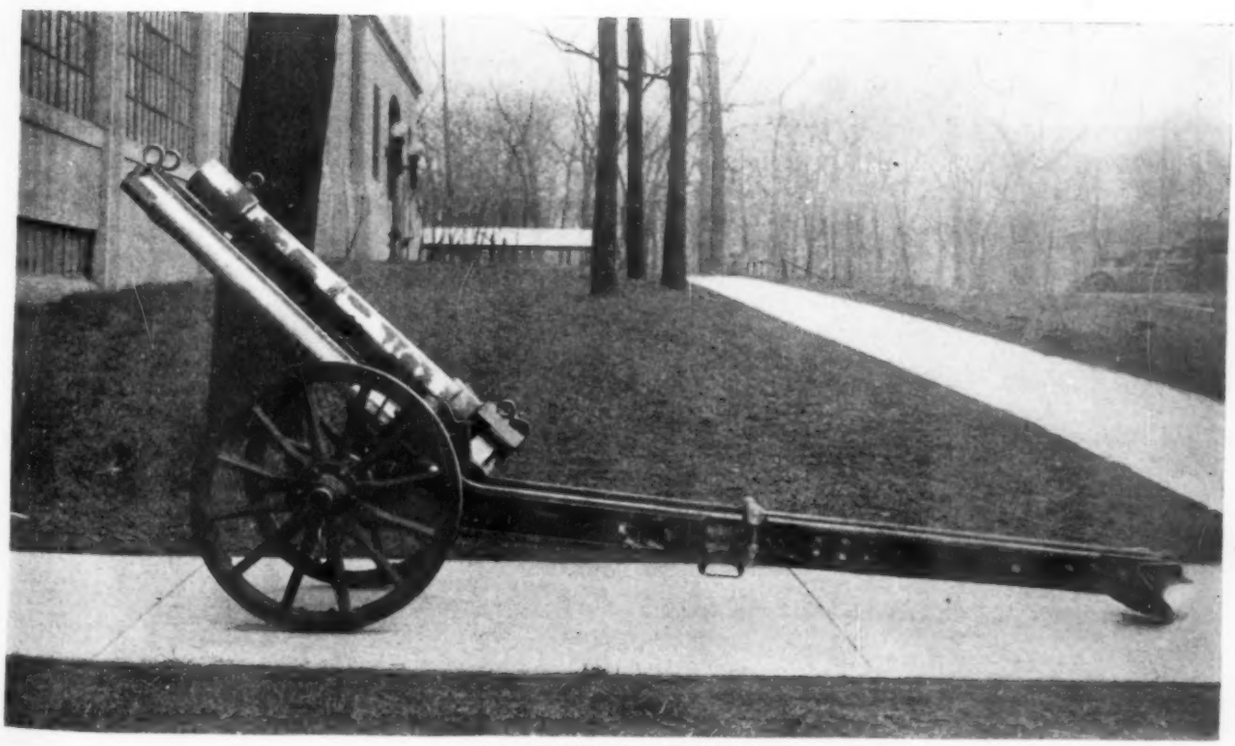
It is hoped that the new material when perfected to a satisfactory degree will possess the following advantages over existing materiel: a greater range; a greater angle of fall when desired, permitting more effective use; greater stability in firing, permitting continuous laying; superior pack loads; and a reduction in weight. It has been found by no means easy to obtain these improvements without sacrifice of the simplicity and ruggedness of the present type of materiel.

TABLE OF CHARACTERISTICS

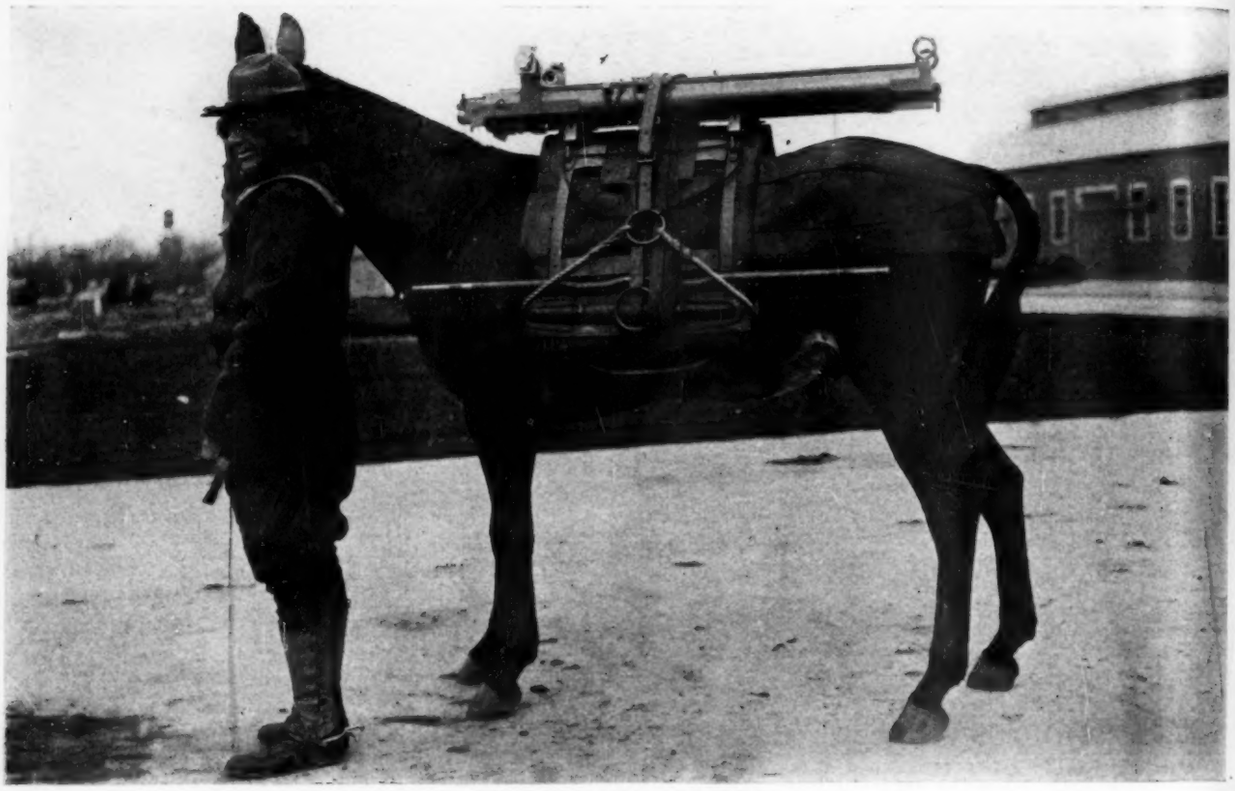
	2.95 V. M. Mtn. Gun	75 mm. Pack Howitzer
Length in calibers	10.73	14.72
Muzzle velocity (maximum)	920 f. s.	900 f. s.
Muzzle velocity, 1st charge	-------	775 f. s.
Muzzle velocity, 2d charge	-------	650 f. s.
Maximum range, yds	4925	6500
Maximum elevation, degrees	27	45
Maximum traverse, degrees	None	5
Weight of projectile, lbs	12.5	15
Maximum recoil, inches	14	28
Minimum recoil, inches	14	18
Weight of gun and breech mechanism	236 lbs.	208 lbs. No. 1 gun 185 lbs. No. 2 gun
Weight in firing position	830 lbs.	850 lbs. No. 1 gun 820 lbs. No. 2 gun
Number of pack loads	4	4



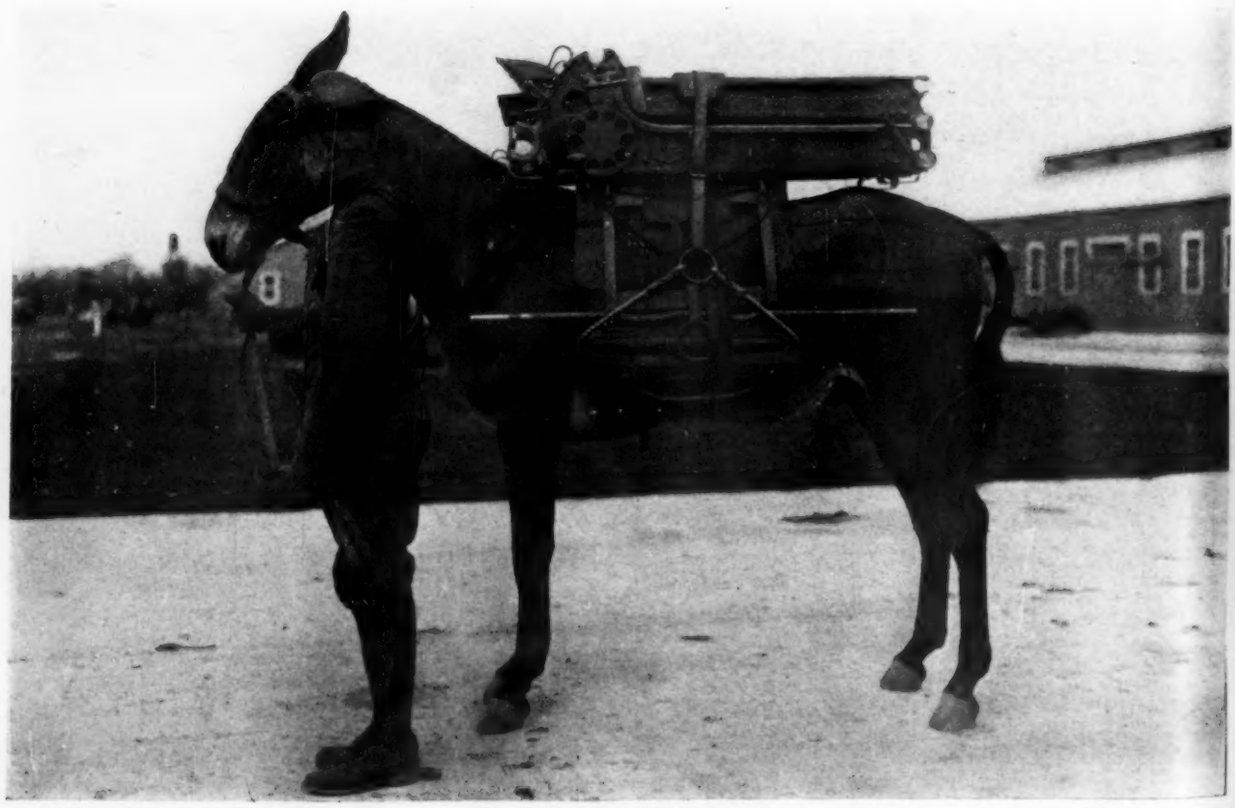
75-mm. Pack Howitzer, Model 1920
Right side zero elevation



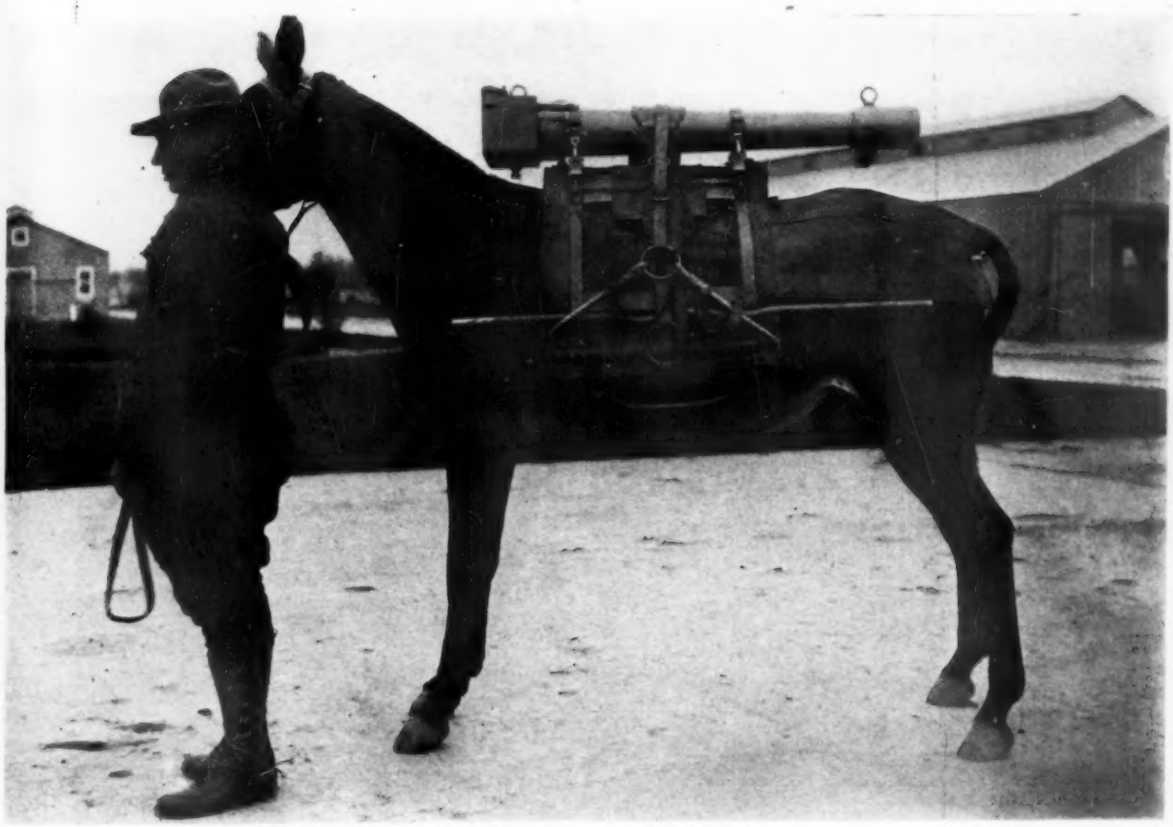
75-mm. Pack Howitzer, Model 1920
Left side 45° elevation



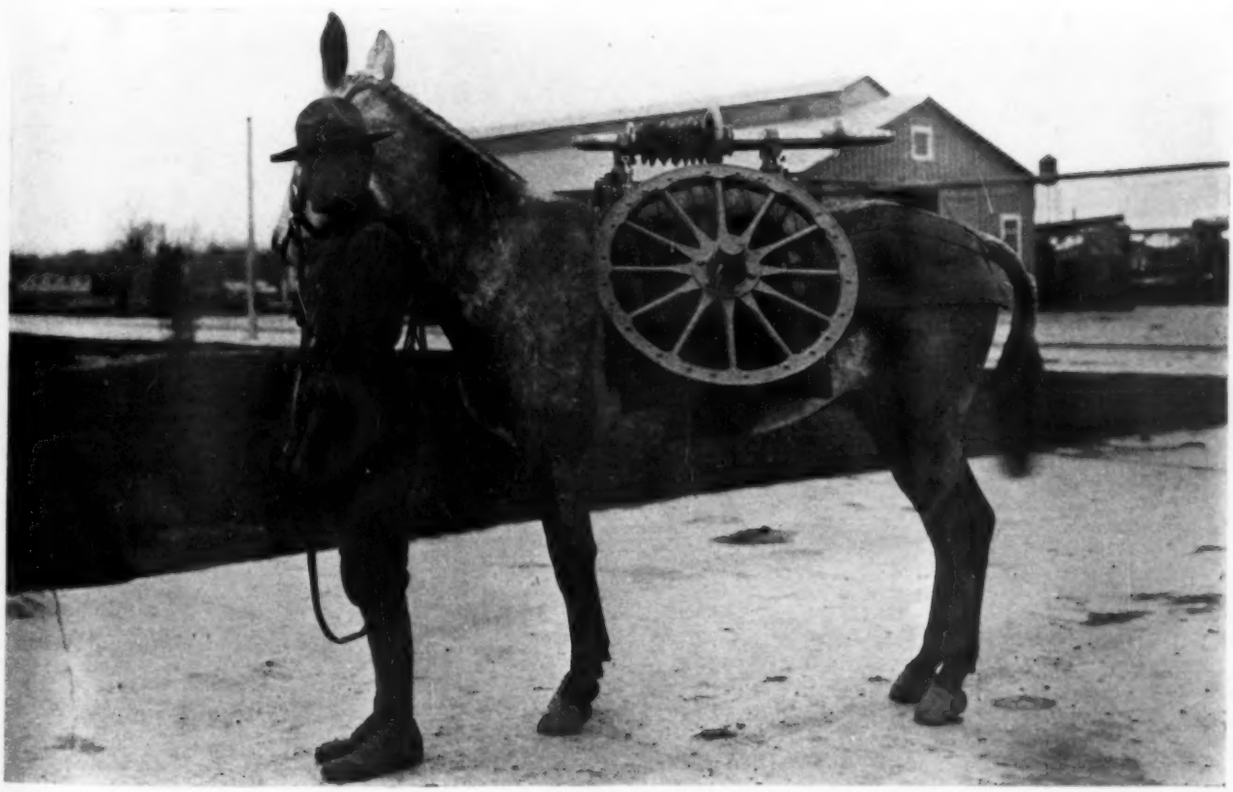
75-mm. Pack Howitzer, Model 1920
Recuperator load



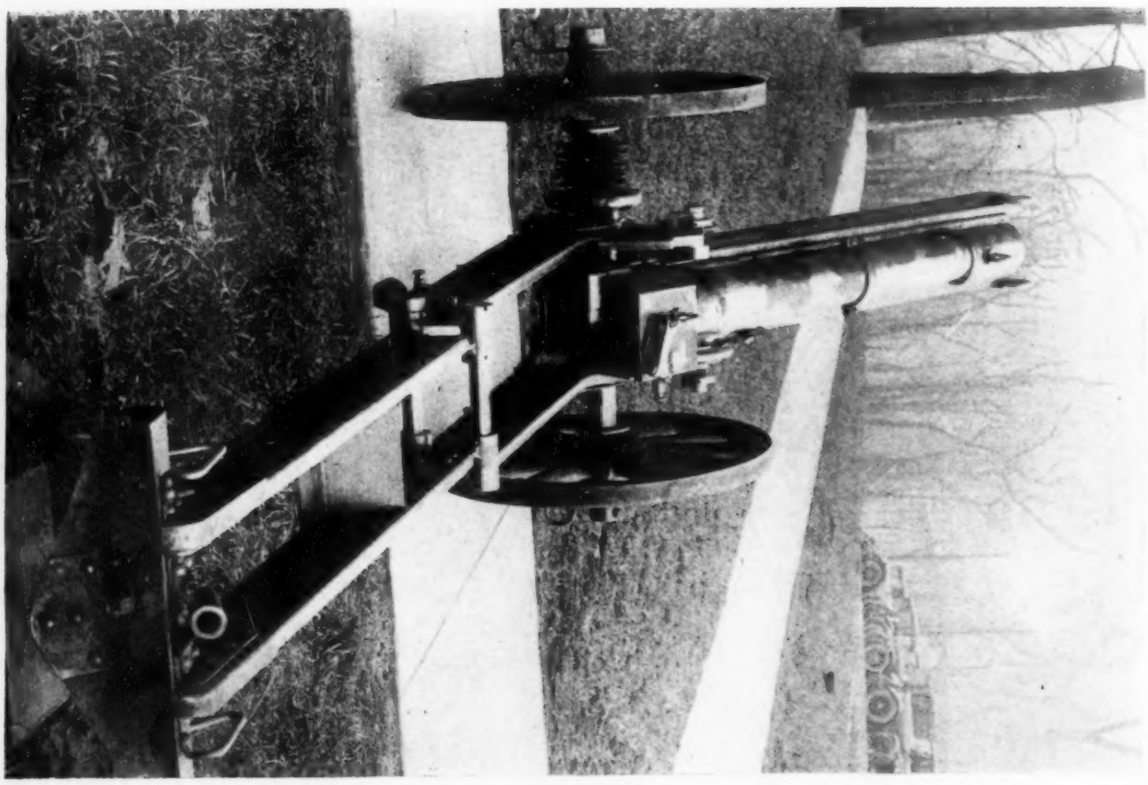
75-mm. Pack Howitzer, Model 1920
Trail load



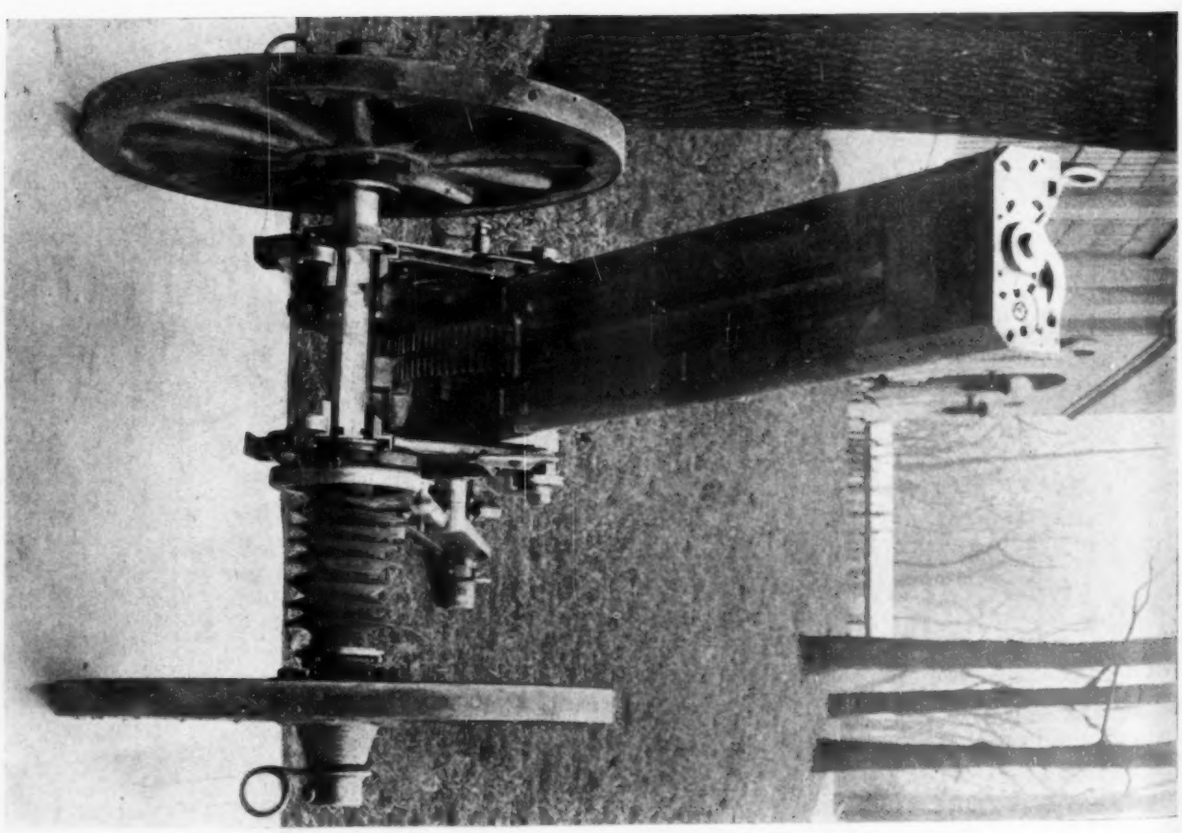
75-mm. Pack Howitzer, Model 1920
Gun load, with cincha



75-mm. Pack Howitzer, Model 1920
Wheels and axle load



75-mm. Pack Howitzer, Model 1920
Rear view full elevation



75-mm. Pack Howitzer, Model 1920
Front view full elevation. Full right traverse

Retirement of General Rice

Chief of Manufacture, Ordnance Department, U. S. A.

IT will doubtless be a matter of great interest and keen regret to every member of the Army Ordnance Association to learn that General John H. Rice, Ordnance Department, U. S. Army, Chief of Manufacture, in the Office of the Chief of Ordnance, has retired from active duty on his own application after more than thirty years' service.

General Rice's service in the Army and in the Ordnance Department has been one of unusual distinction, his war service culminating in the very important appointment as Chief Ordnance Officer of the American Expeditionary Forces in France, with the rank of Brigadier General.

General Rice

General Rice is a graduate of the United States Military Academy, class of 1893, being assigned upon his graduation to the Third Cavalry, in which he served until November 21, 1898, when he was transferred to the Ordnance Department. During his service with the Ordnance Department he has at various times served at the Watervliet Arsenal, Sandy Hook Proving Ground, Philippine Islands, as Inspector of Ordnance in Ohio and Pennsylvania, in Washington in the office of the Chief of Ordnance, as Chief Ordnance Officer of the Southern Department, as Chief of the Engineering Division during the war, first in the United States and later in France, as Chief Ordnance Officer of the American Expeditionary Forces, and upon his return to this country as Chief of Manufacture, Ordnance Department.

In the early days of his Ordnance service, he specialized in carriage design, for both mobile artillery and seacoast artillery, and, through demonstrated efficiency and ability, gained the position of Chief of the Carriage Division of the Ordnance Department, which position he held at the beginning of the war with the rank of Lieutenant Colonel. In all of our carriage designs there may be identified excellent features which show the marks of General Rice's ability and good judgment. Up to the period of the war, General Rice served under General Crozier and was one of the wheel horses of the very efficient team developed by General Crozier while he was Chief of Ordnance in the decade prior to the World War.

At the beginning of the war, the Carriage Division, under General Rice, consisted of six officers, nine clerks and about seventy-five draftsmen. It had charge for the entire army of design, procurement, inspection, test, issue, repair and maintenance of all machine guns, special motor equipment, tanks, and all classes of gun carriages for field artillery, railway artillery and coast artillery, with their equipment and accessories.

From the beginning of the war until December, 1917, when the Ordnance Department was reorganized, the Carriage Division, which General Rice reorganized and expanded, placed orders and contracts for about $700,000,000 worth of materials and facilities and transacted all the business of design, inspection, etc., connected with this work, and at the same time increased the personnel during the period by 188 officers and 1,336 civilians and enlisted men, or 1700 per cent. The increase in business as represented by funds involved was approximately 1000 per cent, and the actual business was much greater.

At the time of the reorganization of the Ordnance Office on January 1, 1918, General Rice was made a Brigadier General in the National Army and designated as Chief of the Engineering Division, which he organized and operated. The Engineering Division was charged with the duty of preparing and procuring designs, drawings, and specifications for all classes of Ordnance material and it actually did a great deal of work in connection with procurement

and inspection. On June 15, 1918, there were in the Engineering Division in Washington about 400 officers and 1,550 civilians and enlisted men.

General Rice went to France in June, 1918, as Chief of the Engineering Division of the Office of the Chief Ordnance Officer, A. E. F., for the purpose of co-ordinating engineering activities in the United States and abroad. He organized and operated the Engineering Division in France until the first of October, 1918, when he was appointed Chief Ordnance Officer of the American Expeditionary Forces, and in this position had charge of approximately 2,000 officers and 22,000 enlisted men, as well as procurement abroad, storage, issue, repair and maintenance of ordnance for a maximum of about 2,000,000 troops. After the Armistice and until his return to the United States in August, 1919, he had charge of all Ordnance work in France.

The character of General Rice's services as Chief Ordnance Officer, A. E. F., was such as to elicit from the Commanding General of the A. E. F., General Pershing, a letter of commendation and appreciation for the very excellent services rendered by the Ordnance Department.

After the Armistice the Ordnance Department was reorganized and contracted to a peace-time basis, being organized into two operating groups, the Manufacturing Service and the Field Service, with an overhead technical organization known as the Technical Staff, functioning as technical advisers to the Chief of Ordnance. General Rice was assigned to the very important position of Chief of the Manufacturing Service and operated this service with his usual efficiency and thoroughness up to the time of his retirement on July 1, 1921.

Among the many important duties performed by General Rice was that of presenting to the Congress the Ordnance estimates each year covering development and manufacturing work. By his frankness, honesty and thorough knowledge of his subject, he was able to instil in the Committee Chairmen a feeling of confidence in him and in his estimates and in the sincerity of the Ordnance Department.

It is very difficult to express in words the great value to the Ordnance Department of the many years of faithful service of General Rice. His retirement is a distinct loss to the Department and one from which it will not readily recover. It loses a man of the soundest judgment, a man with a keen analytical mind, the fullest technical knowledge and wide experience in the business side of Ordnance operation. General Rice commanded the respect, admiration and affection of not only the commissioned personnel, but in like degree the civilian personnel under his charge.

General Rice was one of the original enthusiasts in the organization of the Army Ordnance Association and was one of those whose foresight enabled them to perceive and to weigh the manifold advantages to the Ordnance Department and to the country by the organization of those individuals engaged in munitions manufacturing during the war, from the Government side and from the manufacturers' side, into a working organization which would serve as a right hand to the Ordnance Department in keeping alive the art of munitions design and in stimulating interest in preparations for munitions manufacture.

Upon the eve of General Rice's departure, more than fifty Ordnance officers who had served under him at one time or another, banded together to tender him a farewell dinner. This dinner was held at the Army and Navy Club on the evening of June 16th, and was planned and given by the younger officers of the Ordnance Department as a token of the affection and respect which they hold for General Rice and as a testimonial of their high esteem for him as a man. It is seldom in military circles that an officer can so combine military discipline, dignity and efficiency with good fellowship and a keen understanding and consideration for the feelings of his subordinates. General Rice throughout his work in the Ordnance Department possessed in a high degree both the elements of military leadership and human understanding. In addition to the officers giving the dinner, and the guest of honor, there were present as guests the Chief of Ordnance, Major General C. C. Williams, and the Assistant Chief of Ordnance, Brigadier General W. S. Peirce. General Williams made a brief address citing the valuable services and achievements rendered by General Rice and his successes in various activities throughout his career in the Ordnance Department, and expressed the hope that General Rice would live in the minds of all present as an example and inspiration in their work. General Peirce made a brief talk touching upon the severe loss which the Ordnance Department will sustain by the retirement of General Rice, and expressed his admiration for General Rice, not only as an Ordnance officer, but primarily as a man—a man who could command the respect of his fellow-beings and inspire those associated with him to give all that was in them to the work in hand. It must have been a source of pride to General Rice to feel that so many of his associates desired to show their genuine regret at his retirement, their sincere appreciation for him both as an officer and as a man, and to know that each and every one of them was his sincere friend and wished him well in whatever pursuits he might in future years follow.

Official recognition of General Rice's work is shown by the award to him by our President of the Distinguished Service Medal for his services in this country and in France, and the award to him by the French Republic of the decoration of Commander of the French Legion of Honor.

Organization of New York Post Army Ordnance Association

ON June 15, 1921, the New York Post, Army Ordnance Association, was formally organized at an enthusiastic and well-attended meeting held in the large auditorium of the Engineering Societies' building on 39th Street.

The meeting was called to order by Maj. Gen. C. C. Williams, Chief of Ordnance, who spoke in part as follows:

I think as time goes by we should commemorate the efforts that we had to make to form the organizations necessary for the production of war materials and to get the industries of the country changed from their given peace-time production to the production of war munitions. I think the memory of that time is rapidly fading from our people and it therefore remains all the more necessary for us to thoroughly realize that we should keep alive and hand on the results of our experience as far as possible for us to do so, should we again be faced with exactly the same problem. We do not know when it may come. The condition of the world is certainly not one of very great stability at the present time. Of course, everybody hopes that we will not have to do it, but we should be ready to take it up again and one way to do so was by forming the Army Ordnance Association, our object being to salvage as much as possible the experience we had during the last war. I think that the Association has accomplished a very good purpose. It has held a good many of the officers and of the people engaged in the production of munitions together, and it can keep the members of the Association pretty well in touch with what we are doing.

The formation of this Post here in New York, in the 2d Corps Area, combining the Army Ordnance Association, and the Ordnance Reserve Corps officers, is a very good thing. The Association will be of mutual benefit, and we hope to get all the reserve officers to come in and carry along as far as we possibly can the work of the Ordnance Department in its preparation for war. I think it is a very happy thought in forming this Post and I am sure it will be of great benefit to us. I wish you all success. I am very glad to meet you this evening.

General Williams then introduced Gen. Guy E. Tripp, Chairman of the Board, Westinghouse Electric and Manufacturing Company, as Temporary Chairman of the meeting. In accepting the chair General Tripp made a brief address outlining in general terms the purpose of the meeting, at the end of which he introduced Col. M. L. Brett, Ordnance Representative in the Office of the Assistant Secretary of War. Colonel Brett delivered a splendid address on the War Plans of the Ordnance Department, illustrated by stereopticon. At the conclusion of Colonel Brett's address, organization of the local Post was proceeded with. The following officers were elected:

President, Guy E. Tripp
First Vice-President, Col. C. E. Warren
Second Vice-President, Maj. A. W. Maish
Secretary and Treasurer, Capt. H. S. Wilkins

Executive Committee

Guy E. Tripp, Chairman.
A. W. Maish, Vice Chairman.

O. R. C.	*A. O. A.*
Col. C. E. Warren,	James Farrell,
Col. John R. Delafield,	H. B. Hunt,
Lieut. Col. O. H. Fogg,	C. C. Jamieson,
Lieut. Col. C. G. Mettler,	W. H. Marshall,
Maj. J. M. Boyle,	Samuel F. Pryor,
Maj. R. D. Coombs.	E. R. Stettinius.

Capt. H. S. Wilkins, Secretary.

After accepting office as President of the New York Post, General Tripp appointed the following permanent committees:

Programs

Lieut. Col. C. G. Mettler	F. C. Bull
Maj. J. M. Boyle	H. B. Hunt
Maj. F. W. Roller	W. H. Linn

Membership

Lieut. Col. O. H. Fogg	F. P. Lindh
Maj. R. D. Coombs	A. L. Loomis
Capt. W. M. Cory	H. B. Machen

Military Preparedness
The Corps Ordnance Officer, Ex-Officio

Col. C. E. Warren	Lieut. Col. William Libby
Col. John R. Delafield	Maj. J. S. Buist

Industrial Preparedness
The Corps Ordnance Officer, Ex-Officio

W. H. Marshall	J. E. Fullam
C. C. Jamieson	W. J. Hawkins

and then called upon Colonel Shartle, Assistant Chief of Staff for War Plans in the 2d Corps Area, to deliver an address on "Organization of Reserves."

On conclusion of Col. Shartle's address, the Hon. J. Mayhew Wainwright, Assistant Secretary of War, spoke in part as follows:

Mr. Chairman and Ordnance Officers of the Reserve Corps: I congratulate you most heartily upon the successful organization of this association and I trust in all your proceedings there will be the same equanimity and smoothness which governed this initial meeting of your organization. It is quite inspiring to see such an honest sentiment. You all know that union and harmony spells strength and certainly this organization makes a very good start. It is inspiring to see a lot of gentlemen like you gather here together to-night, evidencing by your presence and joining this association that your desire to serve your country has not been satisfied, and that you are ready and willing to give it your services in time of war. This organization will be a very valuable standby unit to promote any further general effort required by our country. The presence here of the Chief of Ordnance of the United States Army and the other distinguished officers of the Army who are here present, and the fact that as patriotic a citizen as General Tripp has consented to serve as the President of this organization, testifies to its importance. I might say that I am here at the request of General Williams, the Chief of Ordnance, who considers this organization to have a most important function and hopes that it will be the precursor of the organization of units such as this throughout the United States.

It is interesting and imporant in its relation to the duties that devolve upon me in the office that I hold. You must be aware that under the law that has been referred to, the Act of June 4, 1920, the Assistant Secretary of War has cast upon him the very important duty of supervising not only the purchase and procurement in time of peace, but, as the law says, the supervision of the service of any quick provisions or mobilization of material and industrial organizations to meet wartime needs. In other words, it falls to the lot of the Assistant Secretary of War to assume that there shall be at least a sufficient plan to provide, as far as a plan can provide, for the assurance of material and equipment in time of war. This means the co-ordination of the various supply departments of the Army and the supervising of their activities. It devolves upon him to see to it that each of the supply departments of the War Department shall have an adequate plan and has made ade-

Continued on page 49

ARMY ORDNANCE

VOL. II JULY-AUGUST, 1921. No. 1

A SINGULAR corroboration of the claim that the American .45-caliber automatic pistol furnished by the Ordnance Department during the World War was far superior to similar hand weapons in use by other armies is found in two incidents related in the *Cavalry Journal* for July, 1921.

The first is a reprint from the French "Revue de Cavalerie" of May-June, 1921, in which Colonel Loir recounts an encounter between a French and a German patrol. The German patrol of six troopers under command of a commissioned officer was surprised by the French patrol and immediately abandoned its leader, hotly chased by the French patrol except for the French non-commissioned officer in charge who remained behind to enter into single combat with the German officer. As the French patrol followed in pursuit of the Boche, they passed in file at a gallop in front of the German officer, and according to Colonel Loir:

> The latter fired and hit three horses with three shots at a distance of 30 paces. The French non-commissioned officer, armed with his lance, galloped down upon him and charged him. The officer fired a fourth round, which left a very visible mark on the leather leggin of the non-commissioned officer, and springing aside he avoided the lance. The non-commissioned officer threw his horse about and charged the second time. The officer fired a fifth round, which glanced along the thumb of the lancer's bridle hand, again bounded back, and a second time avoided the shock. With admirable obstinacy, the non-commissioned officer a third time came back to the charge. The officer fired a sixth ball, which, like the five others, found its mark and hit the horse in the point of the shoulder, passed under the skin, and lodged under the saddle, where we found it some days later. A third time he avoided the shock. Undaunted, always master of his horse, and retaining his presence of mind, the non-commissioned officer again made an about and charged for the fourth time. The German then lost his head, believed that he had no more cartridges (he had two more), turned and bolted. Naturally he was struck at once to the ground by a blow of the lance in the back.

The fate of this German officer, armed with a German pistol, who, in spite of the fact that he registered six hits out of six shots with a weapon whose efficiency he backed with his life, was eventually struck through the back with a lance is in striking contrast to the incident related by Capt. Ernest N. Harmon concerning the part played by the Second Cavalry in the St. Mihiel offensive in September, 1918. In proceeding toward Vigneulles he states:

> The men were falling back to the cross-roads in good order, when suddenly a machine gun opened up on the column from a small trail leading from the main road on the right. This was on our unprotected flank. The Germans had allowed our patrols to go by and had brought their guns to the edge of the woods as the column started back. All the men opened fire on the machine-gun crew with their pistols as they passed. All rules as to flank men only firing from column of fours were forgotten. All men fired, with the effect that *the crew of three men were all killed.* Of course, the horses broke into a gallop. The head of the column, being without a leader, dashed past the cross-roads before an officer could get in front. A second machine gun opened fire from the left. *The crew hardly fired before they were all killed by the fire of the troops as they passed.* Both guns were about twenty yards off the road. The time of firing was short. However, the only reason many of our men were not killed is the fact that the aim was low as for infantry and our column was moving so fast. No commands to fire were given our men; the firing was done from a sense of self-preservation, and was effective. After this incident *the men had all the confidence in the world in their pistols.*

By another incident, Maj. Bradford G. Chynoweth, Infantry, in an article entitled "Cavalry Tanks" points the moral of the two incidents just related, although all three articles are published without any relation one to another:

> For all its glamor, war must be reduced to economics for technical study. Morale is supreme, but *morale must subsist on matter.* The soldier's spirit is one of the eternal things, but *in the soldier's hands we must place the increasingly powerful weapons* that the increased wealth and knowledge of nations can provide. As the man is the unit of courage and spirit, the dollar is unit of equipment. It is necessary only to so adjust our equipment that in war, when our resources of men and of money are taxed to the utmost, the critical moment will find us with sufficient reserves of both. Napoleon with muskets would suffer before the veriest mob of to-day equipped with machine guns. Nations entered the World War with too many men and not enough machinery. In a mechanical age we must devise machinery to increase the concentration of power for our troops.
>
> The growing demand for the introduction of machinery in war cannot be overlooked. We are just beginning to open the fields of mechanical exploitation. If we would play our parts in the wars of the future and attain success, we must become modern and employ the forces made available by the advance of human knowledge. There must be continued concentration; there must be machines; there must be weapons of a sort that neither man nor beast can transport; there must be tanks. If these serve to complicate the problems of supply and tactics, we can only realize that the entire trend of modern activity is toward complication, and must understand that we in the army cannot escape the general law.

The importance of providing superior Ordnance as a factor in upbuilding morale of combat troops, aside from its intrinsic value as a weapon, is being more and more appreciated. However, but few of those who acclaim the superiority of this piece of Ordnance, realize the years of tedious labor behind the perfected American automatic pistol which so obviously increased the morale of troops armed with it. During the Philippine insurrection numerous instances were

reported where American soldiers defending themselves against mad Moros with the old .38-caliber Army revolver were boloed to death by savages they had mortally wounded but whose onrush carried them through our lines to take at least one life before their own expired. The old ".38" would kill—eventually—but lacked stopping power. To correct this condition, and save the lives of American soldiers of a later generation, two Army officers, Maj. Louis A. LaGarde, of the Medical Corps, and Capt. (later Brigadier General) John T. Thompson, of the Ordnance Department, were in 1903 assigned by the Secretary of War to determine upon the most suitable size, weight and composition of bullets suitable for a service revolver or pistol. From then until 1911, when the perfected pistol was issued to the service, was a period of experiment and test, modification and remodification, which bore fruit on the field of battle to the great benefit of our soldiers.

War is not a pleasant thing to contemplate in any of its aspects, and perhaps the most unpleasant phase of all is to concentrate in peace times upon producing weapons of greater and greater efficiency. Yet failure to do so upon the part of those charged with this duty will eventually be felt on the field of battle and the heaviest toll will be paid by those who now comprehend little of the importance of and decry the necessity for development of superior Ordnance in the light of World War experience.

The Nominating Committee of the Army Ordnance Association has submitted the following report:

July 15, 1921.

To the Secretary of the Army Ordnance Association:

The Nominating Committee of the Army Ordnance Association, appointed pursuant to Paragraph 37 of the By-Laws, submits the following nominations for officers and directors of the Association for the year beginning October 1, 1921:

For President—
BENEDICT CROWELL

For Vice-President—
W. W. COLEMAN

For Directors—
(To Serve Two Years)
GUY E. TRIPP
SAMUEL McROBERTS
WALDO C. BRYANT

Respectfully submitted.:

JAMES A. DRAIN, *Chairman,*
A. Y. LEECH, JR.,
H. C. SHERIDAN,
C. C. SHEPPARD,
A. B. RICHESON,
Committee.

Ballots for the election of officers and directors of the Association for the ensuing year, which are to be marked by members of the Association and returned to the Secretary prior to Twelve Noon, Tuesday, September 6, 1921 will be mailed from the Secretary's Office on July 31, 1921 These ballots are supplied with blank spaces for the addition of other nominations which any of the members may choose to make.

Organization of New York Post, Army Ordnance Association

Address of the Assistant Secretary of War

Continued from Page 47

quate preparation to meet any emergency that may arise, and in connection with that it requires that I shall see to it—The Assistant Secretary of War shall see to it—that there is an adequate plan by which the industrial resources of the country may be again put in action and speeded up in the best way possible to supply the needs of the Army in time of war.

This organization particularly will be the connecting link, we might say the liaison, between the War Department and the great industrial organizations and establishments; the great industrial power of the nation which must again go into action in order that we may fight a war successfully. In other words we must see to it that as far as it is possible there are plans made for adequate provision so that when we enter the next war, if it shall be our fate to have to make a similar effort such as fell to our lot recently, that we will not be in the same situation that we were on the 6th day of April, practically without any plan of preparation.

It is almost quite too obvious to state that the problem of industrial preparedness is just as important, if not more important because it is more difficult and involves much more intricate problems, than the problem of the mobilization of the man power. The mobilization of material resources must go hand in hand and keep step and pace with the mobilization of the man power. I have been in office but a short time, but I have been astounded and I think that the public of the country has yet failed to realize the tremendous effort that was made in this last war and the marvelous things that were accomplished, not only by our soldiers upon the fighting lines but by our business and industrial people, and it is evident that in any other major effort of operations the same kind of a speeding up of industry must be made.

It would seem singular to me, although plans have been developed for the organization of units and armies based upon the experiences of the war that no plan had been developed, and there appears nowhere in the War Department any formulation of a plan, to meet the industrial effort that will be required. Councils of national defense and many other agencies which were created have passed out of existence, leaving behind masses of reports, tons of documents and statistics, but apparently no one, or no set of men, has as yet undertaken to provide for an organization, a real government organization, to meet the industrial situation in the same way that they have provided for the new military organization. Now, it is with the assistance and advice of the gentlemen who have had experience not only in the service of our country in uniform but of those other and capable patriotic citizens who put their hearts and their efforts and the entire power of their industrial organizations practically at the disposal of the Government that the strain can be met, and I expect within a comparatively short time, because my department associates are giving serious consideration to the subject, that we will, before long, have developed a proper plan, as wise and as effective a plan as can be devised to be put into effect, when war comes again. It will be necessary of course to enlist the services of thousands of men such as you are, not only men who will put on the uniform again, but we shall have to bring back for council and advice the captains and the leaders of industry to sit at our elbows and to advise us as to what shall be done to provide the things that are needed. Colonel Brett has shown you the tremendous problem involved in the supply of ordnance in the army. Figure then that that is only one part of the problem, that we have besides the Ordnance Department, the other supply departments—the Quartermaster, the Medical, the Chemical Warfare, the Aviation Service and all the other deparments to furnish the varied interests of war. It is a tremendously vast and stupendous problem, but each one we shall meet in the future, I believe, with the assistance of organizations such as this with even greater success than we recently achieved. One thing that we wish to avoid, if possible, namely, that it shall not need be two years between the outbreak of war and the time that production has reached the point where the supply is nearly adequate. The effort must be to have production so speeded up that it can meet at each point the man power.

In conclusion, gentlemen, I wish to assure you of the great interest of the War Department in this organization.

Artillery Division Notes

Relation between weights of cannon and their carriages.—One of the primary limitations upon all designs of mobile artillery is that of weight, as in general, mobility can be best improved by reduction in the weight moved. A cannon of the required ballistics having been determined upon, the designer must first produce the most efficient cannon possible under limitations which may exist in the art of steel manufacture, and then must place beneath this cannon a carriage of minimum weight.

The choice of steel which can be used in cannon construction is quite limited, and for a given muzzle energy and type the weight will depend principally upon the kind of steel used and, of course, also upon the factor of safety desired. Since this factor of safety and the design procedure has been fairly well standardized, there will be little variation in weight, provided the same standards are adhered to in each case. As a matter of fact, as will be noted later, the same standards have not been adhered to throughout all cannon design, nor have the kinds of steel used been always the same, and considerable variation will be found to exist in weights of cannon which should properly be nearly the same.

One way of measuring the efficiency of a cannon is to determine the ratio of the muzzle energy to its weight. Column 5 of the tabulation herewith shows this ratio which has been worked out for various types of service materiel as well as some of the new experimental materiel. It will be noted that this ratio increases with the caliber and power of the cannon. The increase in this ratio follows from the summation of various elements of the theory of design and manufacturing practice, and is somewhat analogous to the efficiency of trucks, for, it will be recalled, the ratio of live load to dead load increases with size.

If we have designed our cannon properly, the designer may, other things being equal, measure his success by the ratio of its weight to weight of the carriage; and the larger this ratio, the more acceptable the design of carriage, other things again being equal.

Column 15 of the tabulation gives the actual ratios existing between cannon and the total unit weights for the types of materiel indicated. It will be noted that the average ratio is about 33 per cent; in other words, the cannon on our present service and experimental materiel weighs about one-half as much as the carriage itself in firing position. It should be added here that this entire discussion pertains to mobile types of artillery carried on wheels, and does not apply to Caterpillar, Seacoast or Railway types, except in its general aspects.

The ratios given in column 15 do not give a fair indication of the merits of some of the designs of carriages, because in some cases the cannon themselves are not efficient as might be.

In order to show the true merit of the carriage design, the cannon have been reduced to a more nearly uniform efficiency, the efficiency weights being given in column 7. Column 16 gives the ratios using the weights in column 7. The weights given in column 7 are calculated only, and not to a high degree of accuracy, and may in some cases be slightly too high or too low, but they are sufficiently accurate for the purpose of general comparison.

The asterisks in column 16 indicate certain experimental types, and it may be interesting to note how good or bad the ratios are in comparison with existing types.

The Pack Howizer Materiel must be considered as a type by itself, and cannot be compared logically with larger or more powerful calibers. The ratio .262 is lower than larger calibers, although slightly better than that of the existing 2.95-inch Mountain Gun. This low ratio is due principally to features which it is necessary to incorporate in order to enable quick disassembly and packing on mules. The 75 mm. field materiel, Model of 1920, has a ratio of .335, which approximates the average. This materiel is, however, of the split trail type, having wide traverse and elevation up to 80 degrees. These characteristics have greatly increased its weight; on the other hand, the gun itself is somewhat heavier than it would be if made of higher grade steel; so, on the whole, the ratio returns to its average.

The 75 mm. field materiel, Model of 1921, is a good illustration of what results from simplicity of construction and limitations placed upon elevation and traverse. This carriage mounts the same gun as the Model of 1920, but permits an elevation of 45 degrees only and has axle traverse. Its ratio, .44, is very good. It may be noted that the actual ratio for these two materials, given in column 15, shows the Model of 1921 slightly inferior. This, however, is due to the fact that the gun, although of the same ballistics, was built to weigh 945 pounds insead of 1,242 pounds, higher grade steel being used. Had the 1,242-pound gun been used, the ratio in column 15 would have been .40. The remaining materiels, marked with asterisk show average ratios of about .33 with exception of the 105 mm. Howitzer, Model of 1921, which has a high ratio. This design is similar to the 75 mm., Model of 1921, and the same remarks as above apply.

It would be slightly more accurate to use the momentum of the projectile and powder gases as a basis of determining the efficiency ratios, but muzzle energy is more commonly considered in connection with cannon and the results obtained by using this muzzle energy are proportional to the result which would be obtained by using momentum.

In conclusion it may be stated that in the case of split trail carriages having wide traverse and high elevation we are fairly successful if the weight of cannon and carriage combined is three times the weight of the cannon; that is, the efficiency ratio is .33. In the case of single or box trail carriages with moderate traverse and elevation up to 45 degrees, the ratio should be about .4. (See table, page 51.)

155-mm. Gun and 8-inch Howitzer Motor Materiel.—The frontispiece shows the new motor carriage for the 155-mm. gun (1920) and 8-inch howitzer (1920), which is now undergoing its preliminary road test at the plant of the Holt Manufacturing Company, Stockton, Cal. Two of these vehicles will soon be completed. The 155-mm. gun is shown in place on the carriage, which carries either this gun or its companion piece—the 8-inch howitzer.

The design of this vehicle incorporates all of the improvements suggested by tests on the Self-Propelled Caterpillar mounts Mark I, II and III for the 8-inch howitzer (Vickers), the 155-mm. (G. P. F.) gun and the 240-mm. (Schneider) howitzer, respectively. The overall height has been made as low as possible, reducing the overturning effect during firing and while the vehicle is of a rugged construction, it has been made as light as possible.

The engine used is a 6-cylinder G-R-V-T Sterling, dual-valve engine, manufactured by the Sterling Engine Company, Buffalo, N. Y. All six of its cylinders are inclined 45 degrees from the vertical to one side, to reduce the overall height to a minimum. Two carburetors, double battery ignition and two exhaust manifold outlets are used. A maximum of 260 H. P. is delivered by this engine at 1,800 R. P. M.

Two types of transmissions are undergoing test for use in this mount to determine which is the most satisfactory. In one type, steering is accomplished by the use of double clutches for each track, while in the other a clutch and planetary gear set is used.

Rubber is used in various parts of the track mechanism to reduce the noise and shock. The motor carriage being large and heavy, the application of rubber is more difficult than when applied to the smaller motor carriage for the 75-mm. gun and 105-mm. howitzer.

The maximum speed expected is 14.5 miles per hour with the engine running at 1,800 revolutions per minute. This high

COMPARISON OF GUNS WITH CARRIAGES

Feb. 25, 1921

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Name of Carriage	Wt. Proj. Lb.	Muzzle Velocity Ft. Sec.	Energy Projectile Ft. Lb.	Wt. Gun Lb.	Energy Proj. Per Lb. Gun.	Energy Proj. Per Lb. Eff. Gun.	Wt. Efficient Gun Lb.	Wt. Gun and Carriage Firing Position.	Energy Proj. Per Lb. Gun and Carr.	Wt. Pwd. Chg.	Momentum Pwd. Gases.	Momentum Projectile.	Total Momentum	Momentum Per Lb. Gun and Carriage.	Wt. Gun ÷ Wt. Gun and Carriage.	Wt. Eff. Gun ÷ Wt. Gun and Carr.
2.95 V. M. Mtn. Gun	12.5	920	166,000	1,236	700	850	196	830	200	.5	2,350	360	2,710	3.27	.285	.236
75 Pack How. M–1920	15.	900	190,000	224	850	.....	223	850	223	.46	2,170	422	2,592	3.05	.262	*.262
3. Field M–1902	15.	1,700	680,000	788	865	900	756	2,520	270	1.5	7,050	800	7,850	3.12	.313	.300
75 Field M.–1916	12.2	1,742	578,000	765	760	.....	643	3,045	190	1.5	7,050	664	7,714	2.54	.252	.214
75 French M.–1897	12.2	1,805	622,000	1,015	615	.....	692	2,657	235	1.5	7,050	690	7,740	2.9	.382	.260
75 British M.–1917	12.4	1,742	590,000	995	600	.....	657	2,887	204	1.5	7,050	676	7,726	2.68	.345	.227
75 Field M.–1920	15.	2,175	1,110,000	1,242	900	.....	1,230	3,660	303	3.	14,100	1,020	15,120	4.1	.340	*.335
75 Field M.–1921	15.	2,175	1,110,000	945	1,180	.....	1,230	2,800	396	3.	14,100	1,020	15,120	5.4	.337	*.440
3.8 How. M.–1917	30.	1,200	675,000	681	1,000	1,000	675	2,961	228	1.67	7,860	1,128	8,988	3.03	.230	.228
105 How. M.–1920	33.	1,500	1,160,000	1,260	920	.....	1,160	3,678	314	3.25	15,200	1,550	16,750	4.55	.343	*.315
105 How. M.–1921	33.	1,500	1,160,000	1,020	1,140	.....	1,160	3,000	386	3.25	15,200	1,550	16,750	5.6	.340	*.385
5-60 Pdr. British Mk. II	60.	2,150	4,340,000	4,858	900	1,130	3,830	12,096	358	9.44	44,400	4,040	48,440	4.	.402	.317
4.7 Field M.–1906	45.	2,050	2,950,000	2,688	1,100	1,100	2,680	8,068	367	7.	33,000	2,880	35,880	4.45	.334	.333
4.7 Field M.–1920	50.	2,450	4,700,000	4,200	1,120	.....	4,260	13,000	362	13.4	63,000	3,840	66,840	5.13	.323	.328
155 How. M.–1918	95.	1,420	2,980,000	2,745	1,090	1,190	2,510	7,600	392	8.	37,500	4,200	41,700	5.5	.362	.330
6 How. M.–1908 M I	120.	900	1,510,000	1,925	790	.....	1,270	7,582	200	3.	14,100	3,360	17,460	2.3	.254	.170
155 How. M.–1920	95.	1,850	5,080,000	4,265	1,190	.....	4,270	13,000	390	14.25	67,000	5,500	72,500	5.57	.327	*.328
155 Gun M.–1918	95.	2,380	8,400,000	8,795	960	1,260	6,660	25,960	323	25.25	118,000	7,060	125,060	4.83	.338	.257
155 Gun M.–1920	95.	2,800	11,600,000	9,200	1,260	.....	9,200	27,000	430	30.1	140,000	8,300	148,300	5.5	.340	*.340
6 British Mk. VIII A	100.	2,350	8,650,000	10,192	850	.....	6,860	22,512	385	23.	108,000	7,360	115,360	5.13	.452	.303
8 How. Mk. VI	200.	1,300	5,280,000	6,552	810	1,340	3,950	19,100	277	10.75	50,500	8,120	58,620	3.07	.342	.207
8 How. Mk. VII	200.	1,525	7,260,000	7,730	930	.....	5,420	20,050	362	17.5	82,200	9,540	91,740	4.6	.386	.270
8 How. M.–1920	200.	1,950	11,900,000	9,000	1,320	.....	8,880	27,000	440	29.5	138,000	12,200	150,200	5.55	.333	*.328
194 Gun M.–1919	184.	2,300	15,200,000	19,250	800	1,440	10,550	36,500	416	51.	239,000	13,200	252,200	6.9	.530	.289
9.2 How. Mk. I	290.	1,187	6,420,000	6,810	940	1,400	4,600	29,100	221	13.	61,000	10,800	71,800	2.47	.234	.160
9.2 How. Mk. II	290.	1,506	10,250,000	9,576	1,070	.....	7,330	35,500	316	26.	122,000	13,640	135,640	3.83	.270	.206
240 How. M.–1918	356.	1,700	16,100,000	10,831	1,500	1,470	11,000	41,296	390	35.	164,000	18,900	182,900	4.45	.265	.272

speed is desirable in that whenever it becomes necessary for the motor carriage to travel in a truck train, it will be possible for it to do so without interfering with the speed of the rest of the train.

Principal Characteristics.

Total weight, fully equipped	pounds	45,000
Maximum gun range	yards	26,000
Maximum Howitzer range	yards	18,000
Maximum traverse, each side	degrees	10
Maximum elevation	degrees	65
Distance from ground to gun axis	inches	65.25
Maximum overall length of vehicle	inches	217
Maximum overall height of vehicle	inches	81
Maximum overall width of vehicle	inches	110
Center to center distance of tracks	inches	92
Width of track	inches	18
Length of track in contact with ground—		
(a) Minimum contact on hard ground	inches	120
(b) Contact with 5″ depression	inches	166
Ground pressure at 5″ depression	pounds/sq. in.	7.5

Road speeds at normal engine speed (1200 R.P.M.)

	Secondary	Primary
Low speed	1.37 M.P.H.	2.32 M.P.H.
Reverse speed	1.92 M.P.H.	3.25 M.P.H.
Intermediate speed	3.7 M.P.H.	6.28 M.P.H.
High speed	5.68 M.P.H.	9.7 M.P.H.
Maximum road speed at 1800 R.P.M. of engine	8.5 M.P.H.	14.5 M.P.H.

Experimental Materiel.—The Rock Island Arsenal now has in process of assembly several of the experimental types of gun carriages which were placed in manufacture some months ago. The most advanced of these is the 75 mm. Gun Carriage, Model of 1921, which has been described by Mr. Gurney in the last issue of Army Ordnance. Assembly of this carriage has proceeded without difficulty, and its submission to proof test is awaited with great interest.

The 3-inch and 4.7-inch Anti-aircraft Carriages are also being assembled. A cut of the 3-inch carriage was shown in the last issue of Army Ordnance. The 4.7-inch carriage is very much the same, except in size of parts. Anti-aircraft materiel from its very nature is highly complicated. In order to permit accurate control of fire against targets moving in three dimensions, the system of sighting and control becomes quite elaborate, and as the accuracy of control depends upon the accuracy of manufacture, the completion of these two carriages has been by no means easy. At a later date it is hoped to give in this journal a complete description of these anti-aircraft carriages, as they possess a number of unique features.

Recoil Systems.—The Artillery Division has recently requested authority to print a volume on the Theory and Design of Recoil Systems and Gun Carriages, which has been prepared by Captain Eksergian, formerly of the Ordnance Department, and now employed by the Baldwin Locomotive Works. Captain Eksergian was, during the war, in charge of calculation work in the Mobile Gun Carriage Section of the Artillery Division, and after the armistice he remained on duty with the Ordnance Department for about a year, in order to place in a more permanent form the great amount of engineering information which was available in the office, but which it had not been possible to consolidate.

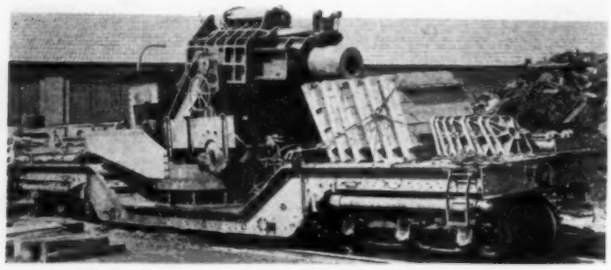
Captain Eksergian has placed in available shape this data covering practice of the Department and has added to it a great amount of original investigation and analysis. While it will only be possible to print a small edition, it is expected that this volume will be of great interest to engineers engaged in the design of ordnance materiel, or to those who are instructors in subjects pertaining to ordnance. The volume will contain chapters on the design of various types of gun carriages and recoil systems used for the first time during the World War.

Optical Glass.—A book on the manufacture of optical glass and precision optics has been prepared by Lt. Col. F. E. Wright, Ordnance Reserve Corps, and is expected to be ready for distribution by September 1st. Colonel Wright was in charge of the production and inspection of optical glass at the plant of the Bausch & Lomb Optical Co. from April, 1917, to May, 1918; the army representative on the military optical glass and instrument section of the War Industries Board from March 15, 1918, until after the armistice; chairman of the army commodity committee on optical glass and instruments under the Director of Purchase, Storage and Traffic from April, 1918, until after the armistice; and in charge of optical systems in the fire-control section of the engineering division of this office from August 4, 1918, to June 16, 1919.

Railway Artillery.—Volume I, a treatise on railway artillery prepared by Lt. Col. W. H. Miller, Ordnance Reserve Corps, is now coming from the press and will be ready for distribution in two weeks. Colonel Miller was in charge of the Railway Artillery Section of the Heavy Artillery Division of the Office of the Chief Ordnance Officer, A. E. F., France, and later in charge of the Heavy Artillery Division. After his return from France he was engaged in the compilation of notes on railway artillery in the volume now being issued. Volume II of this treatise is under preparation.

Railway Carriages on Narrow Gauge Track.—It may be of general interest to Engineers to know that the Ordnance Department has successfully mounted the 12-inch Mortar railway

carriage on a thirty-six-inch gauge track. The 12-inch mortar railway mount, model of 1918, equipped with narrow gauge trucks, on a thirty-six-inch gauge track, is shown in the accompanying photograph.



12-inch Mortar Railway Mount on Narrow Gauge (36-inch) Trucks

The total weight of the 12-inch mortar railway mount is approximately 90 tons. The center of gravity of the mortar, which with its cradle weighs about 30 tons, is carried 9.5 feet above the top of the rail. This arrangement will permit these carriages to be operated over light railroads of this gauge.

The 12-inch mortar railway mount has a range of nine miles with a 700-pound projectile and can be put into action in about 25 minutes after arrival at a designated point.

Sixteen-inch Disappearing Carriage.—The photograph shows the 16-inch Disappearing Carriage which was recently completed at Watertown Arsenal, under erection at the Aberdeen Proving Ground. The gun levers have just been placed in position upon the top carriage. The top carriage which contains the recoil cylinders is clearly shown. The curved casting at the rear of the carriage forms the support for the elevating slide which in turn supports the elevating arm. The next problem in the erection is to lift the gun which weighs approximately 175 tons, into the bearings at the end of the gun levers, which are ready to receive it.

A 16-inch 50-caliber gun will be proof-fired on this carriage during the Third Annual Meeting of the Army Ordnance Association at Aberdeen Proving Ground, on Friday, October 7, 1921.

Another 16-inch 50-caliber gun mounted on a barbette carriage will also be proof-fired during the meeting.

Test of Christie Motor Materiel.—This test of one of the Christie 155 mm. gun motor carriages was conducted at Camp

GETTING READY FOR THE THIRD ANNUAL MEETING, A. O. A.
Erecting 16-inch Disappearing Carriage at Aberdeen Proving Ground

Jackson, South Carolina, under supervision of a Board of officers of the 39th Artillery Brigade, C. A. C. Captain L. A. Miller of this board was proof officer for these same carriages at the Aberdeen Proving Ground. A distance of 1,000 miles was to be traveled on the wheels and tracks of the motor carriage, dependent on the ground conditions encountered, under conditions simulating service requirements.

It was at first decided to check up various parts of the running gear at the end of 200 miles, however, at the end of 109 miles of travel on the tracks, the wear in various parts of the track mechanisms was so excessive that the Board decided to stop the test at this point and record various measurements and data.

After these data had been recorded the test was continued for another 104 miles of travel on the tracks when one of the center wheels broke. This is as far as the test has been reported.

Following is a brief of the results of this test as reported by the testing board at Camp Jackson:

The motor carriage is easily steered and controlled when running either on its wheels or on its tracks. The engine, when driving through the various gear settings seems to have sufficient power to propel the vehicle up any grade or over any kind of terrain upon which the tracks can obtain suitable footing.

Power Plant.—The gasoline consumption—1.5 gallons per mile—is considered as a normal consumption. The oil consumption—.5 gallon per mile—is considered very high, being a ratio of 1 gallon of oil to 3 gallons of gas.

The engine gave off a great deal of blue smoke during the entire run, although the oil level was kept at the proper height, also the spark plugs fouled frequently due to too much oil being consumed.

Christie Self-Propelled Mount for 155-mm. Gun in Firing Position, Aberdeen Proving Ground

The cooling water boiled frequently and the water in the radiator had to be replenished to the amount of .5 gallons per mile. The cooling fan belts stretched and slipped continually and had to be replaced several times.

The connecting rod bearing for No. 3 cylinder burnt out after the first test of 109 miles and had to be replaced before the second run was started. No more bearings have burnt out to date.

Transmission.—The transmission functioned satisfactorily throughout the entire test. No appreciable wear was noticeable on the transmission gears with the exception of the final drive pinion which had worn one-eighth inch on the thickness of each tooth on the pitch line at the end of the second run. The pitch line thickness of these teeth is normally 17/32 inches.

Track Mechanism.—The track mechanism suffered the most wear in the tests to date. Although the tracks have come off several times in demonstrations, no recurrence of this was reported in these tests.

When this motor carriage is operated as a track-laying vehicle the track mechanism consists of a series of hinge-connected plates having teeth or driving lugs riveted thereto, which lugs mesh with slots or recesses in the driving wheel. The track travels over and around four wheels on each side a driving wheel, two center wheels equalized, and a front wheel. Each of these wheels is equipped with two solid rubber tires which roll on the track plates, the track alignment and side thrust between the tracks and wheels being taken by grooves around the wheels between the tires, into which the track driving lugs fit as the wheels pass over the plates.

Due to a peculiarity of this type of drive, the non-driving sides of the track lugs and the non-driving side of the slots in the driving wheel wore excessively three-fourth inches on each track lug and three-fourth inches on each slot in driving wheel. The driving sides of both of these parts showed only a normal amount of wear, one-fourth inches.

As a track-laying vehicle, the center wheels take a good deal of the load. About one-fourth inch had been worn off of the tires on these wheels and their entire surface was badly grooved and cut. At the end of 209 miles of travel on the track, the right rear center broke into two pieces, the wheel dividing around its entire periphery at the track guiding groove, which had been worn thin by the side thrust of the track lugs. The sides of the lugs had also been worn off to the extent of one-fourth to one-half inches in thickness in taking the side thrust of the center wheels.

Considerable wear had taken place on the track connecting pins and the track pin holes. It was found that these wore more rapidly when lubricated than when run without lubrication due to sand and grit mixing with the oil and making an abrasive mixture. The longitudinal sides of the track connecting hinges showed only a normal amount of wear.

General Notes.—No ill effects have been noted on the motor carriage as a whole due to vibration while traveling on its tracks, although the gun traveling lock and the recoil and recuperator rod nuts had to be tightened frequently. Vibration also loosened the bolts on the road wheel rims occasionally.

Oil leaked from the engine crankcase into the transmission case at the rate of one quart per mile, presumably through the cover plates at the crank shaft driving gears. Considerable oil smoke came from the engine cylinders on the lower side of the motor carriage when traveling on a sloping road.

This test is to be continued over the prescribed distance of 1000 miles and further information with a discussion of results obtained will appear in a future issue.

Frankford Arsenal Notes

During the past month a number of preliminary tests of experimental fire control equipment have been carried out and while the results obtained are not yet conclusive, certain general deductions can be made in regard to the serviceability of some of the apparatus.

Balloon Observation Instruments.—The balloon observation instrument described in the previous number of ARMY ORDNANCE has been given a preliminary test at Fort Monroe by the Ordnance Department and has been turned over to the Coast Artillery Board for further experimentation. While the preliminary tests indicate that the stabilized instrument will give satisfactory results under favorable weather conditions, it was evident that such results could not be obtained in unfavorable weather, without an increase in the size and weight of the apparatus beyond what could be considered practicable.

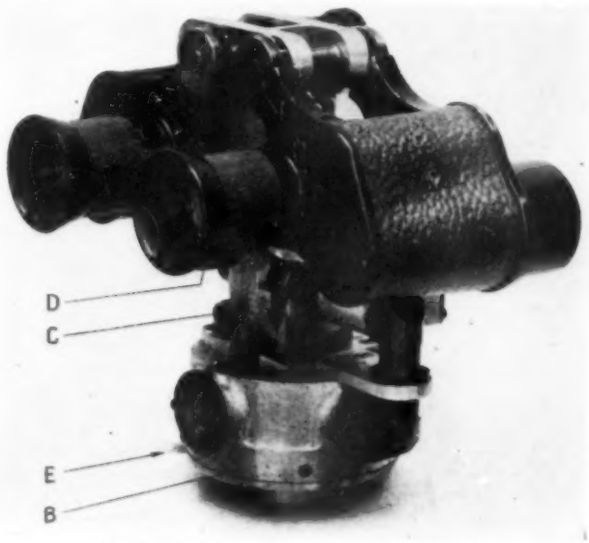
So far as can be determined at present, the most practicable solution of the problem of balloon observation appears to be in the development of the hand type of observation instrument, now under test by the Artillery Board. Experience indicates that the captive balloon will be available as an observation station only during excellent weather conditions and since these conditions are not the ones normally encountered, it would appear inadvisable to provide an elaborate equipment which in all probability could not be used when most needed. The hand observation instrument now under test by the Coast Artillery Board will, after certain modifications, probably best satisfy the conditions to be met.

Range Correction Board, Model 1921.—A preliminary test of the Range Correction Board, Model 1021, described in the last ARMY ORDNANCE, has been made by the Coast Artillery Board. The device appears to meet all requirements in a highly satisfactory manner but will be given a service test before a final report is made.

Optical Plotting Board.—The sample Optical Plotting Board furnished to the Coast Artillery Board for trial has been given a preliminary test and will be used, as far as practicable, in a service test during the coming target practice season. It is especially adapted for use with the balloon observation instruments above referred to, hence could not be completely tested until the latter had been delivered. The Coast Artillery Board was favorably impressed with several features of the board and has recommended the manufacture of a sample on a reduced scale for a service test. The new board, in addition to optical and mechanical features similar to the original, will embody a number of novel ideas such as the indication of readings by counting devices instead of by scales, etc. It is anticipated that the longest dimension of the new board will not exceed 5 feet, that ranges up to 50,000 yards may be calculated with the required accuracy, that its operation will be rapid and that the board will be absolutely universal, that is, adapted to any practicable position of battery and base end stations.

Airplane Observation Instrument.—There has recently been completed at Frankford Arsenal, the Airplane Observation Instrument shown in the accompanying photograph. It will shortly be forwarded to Fort Monroe for test by the Artillery Board.

The instrument is designed to permit the observer in the airplane to locate a target with reference to himself. When the data so obtained is transmitted to the firing battery, the latter will then be able to locate the target, provided it knows the location of the plane. In case the plane is visible, it can, of course, be located by any one of the various means now available for locating visible targets. In case the plane is out of sight, some such method as the radio compass will be required for determining the position of the plane. The purpose of the present instrument is to permit such a system to



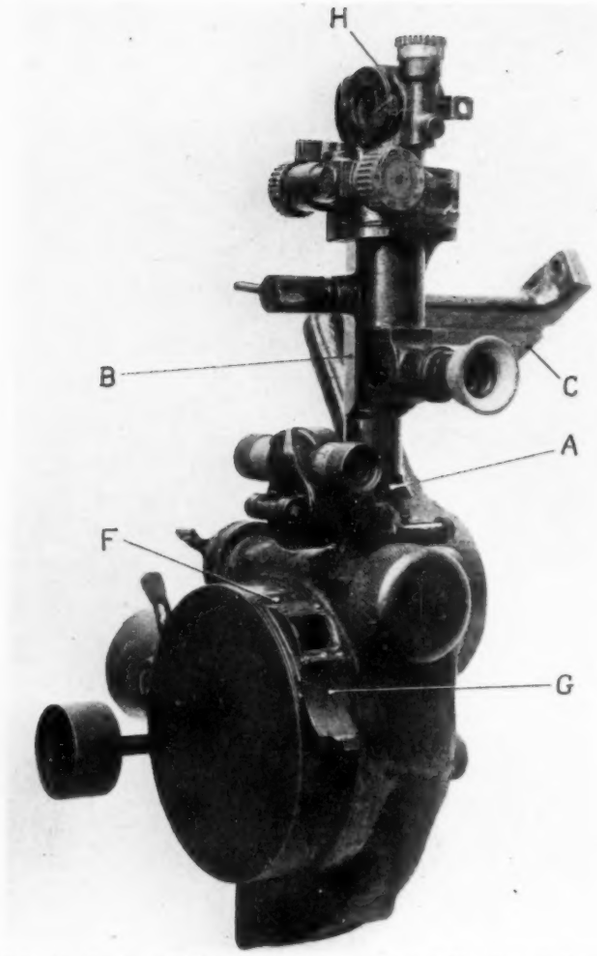
Airplane Observation Instrument (Hand Type)

be tested. If successful, this method will permit the location of targets at any practicable range, regardless of conditions of visibility from the shore, and in any weather in which a plane can operate. It is hoped that the accuracy obtained will be sufficient to permit salvos being placed close enough to the target for spotting purposes, after which the fire can be adjusted by spotting.

As shown in the photograph, the Airplane Observation Instrument consists of a pair of ordinary binocular field glasses A, to which has been attached a liquid compass B, with graduated card and a level vial C. The compass and level are arranged to rotate about an axis perpendicular to the plane of sight, so as to remain leveled when the line of sight of the telescope is depressed to the target. The rotation is accomplished by means of the knob D, which is convenient to the hand when holding the instrument to the eye. Suitable scales on the body and on the knob indicate the amount of the angular depression of the line of sight.

Arrangements are provided in the optical system whereby the level bubble and the compass card are both visible in the eye-piece while the target is being observed. A clamping knob E is provided for dampening the movement of the compass card or for locking the same after the observation has been made.

The method of using the instrument is as follows: The binoculars are directed at the target and held so as to keep the latter as closely as possible on the cross wires, while the



Schneider Quadrant Sight for 155-mm. Gun and 8-inch Howitzer Carriages

knob D is turned until the level bubble appears central. The compass clamp E is then forced inward and when it is apparent that the card has come to rest, the clamp is released, fixing the card in position. The instrument is then removed from the eye and the magnetic bearing of the target, as well as its angular depression, with reference to the airplane, are read off for transmission to the battery. It is assumed that the altitude of the observer is known, hence the data obtained is sufficient for the location of the target with respect to the plane.

The chief advantage in the use of an instrument of the above description is that it permits the observing plane to operate at a considerable distance from the target, which, of course, would be the normal conditions under which it would have to observe. It may, of course, be used with equal facility from a captive or from a dirigible balloon, or from an airplane.

Due to the severe conditions under which a balloon or an airplane observer must work, it is not to be expected that exact results can be obtained by the use of the above or of any other instrument. Observations will at best be approximate ones, the closeness of the approximation depending on the means provided, the skill of the observer, the conditions existing at the time, etc. In the above instrument, the level bubble and compass card are purposely constructed to act slowly, so as to minimize the effect of vibration, and as a result of this lack of sensitiveness, the accuracy is reduced. Experience alone will determine what accuracy can be obtained, and what compromise must be made between the opposing factors of accuracy and insensitiveness to vibration.

Experimental Sight Mountings for the 75 mm. Gun Carriage, Model of 1897, M1.—The sight used at present on the above mentioned gun carriage is the original sight, model of 1901, of French design (Fig. 1). It consists principally of the sight bracket (A) which is bolted to the left hand rocker arm, the azimuth or deflection mechanism (B), the angle of site mechanism (C) and the collimator sights (D) and (E).

The collimator sight not being of the telescope type renders the observing of objects not discernible by the normal eye impracticable; therefore direct fire on such objects is rendered somewhat difficult. With the above mentioned conditions prevalent, it will therefore be necessary to equip the carriages with a more suitable sighting system, preferably one using the panoramic sight, model of 1917.

The experimental sight mountings, types A and B shown in Figs. 2 and 3 respectively, have been manufactured to meet

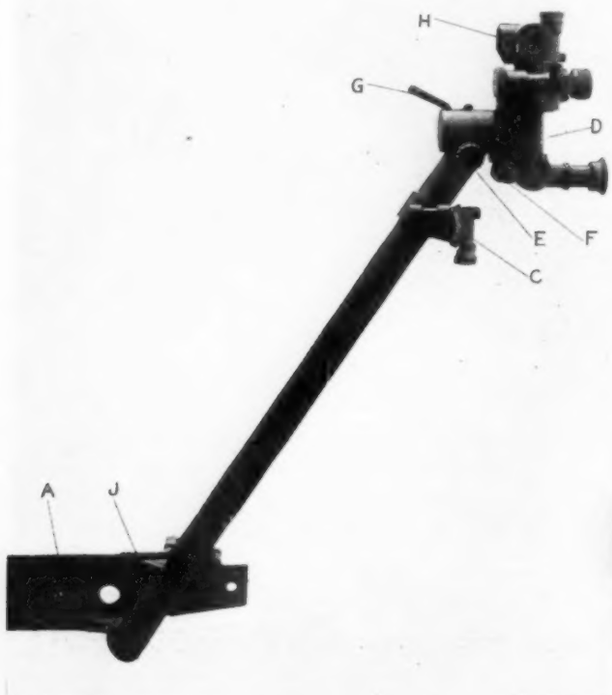


Fig. 2. Frankford Arsenal Experimental Sight Mountings for 75-mm. Gun Carriage (Model of 1897M1)

Fig. 3.

the requirements and have been shipped to Aberdeen Proving Ground for application to the gun carriages and test.

The experimental sight mounting, type A, Fig. 2, consists of the bracket (A) into which is inserted the extension (B) upon which is mounted the angle of site mechanism (C) and the sight support (D) which can be cross-leveled by the knob

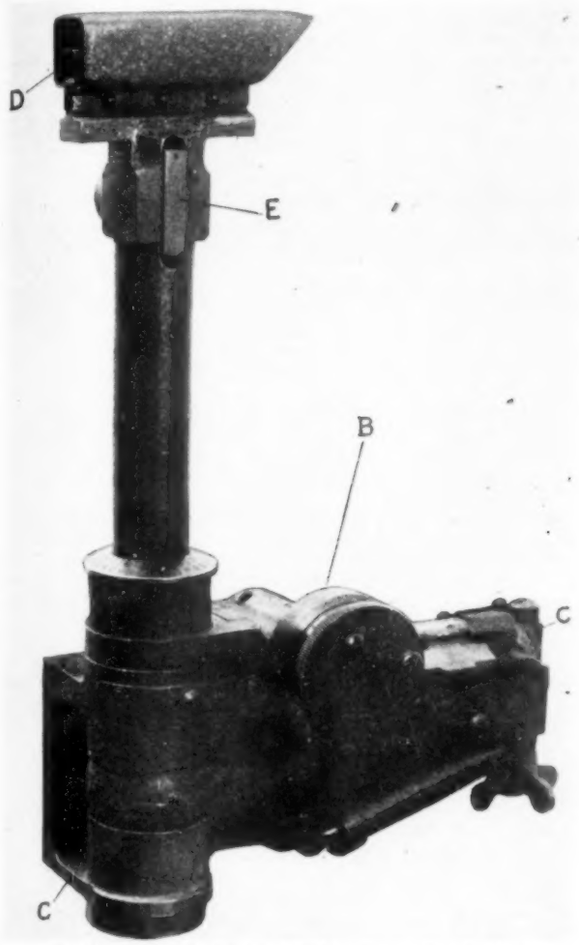


Fig. 1. French Sight (Model of 1901) for 75-mm. Gun Carriage

(E) and clamped by the lever (G). (F) is the cross-level. (H) is the panoramic sight, model of 1917. The extension (B) can be withdrawn from the bracket (A) by releasing the clamp screw (J).

The experimental sight mounting, type B, Fig. 3, is practically similar to the type A, except that the extension pieces are of sheet steel which are in turn riveted fast to the left hand rocker.

Modified Quadrant Sight, Model 1918.—The Schneider Quadrant Sight, or Quadrant Sight, Model 1918, which will be used with the 8-inch Howitzer and 155-mm. Gun Carriages, Model of 1920E, has, for these carriages, been modified in certain respects to overcome difficulties experienced with the original sight. If the modifications made prove satisfactory, it is probable that they will be applied to all quadrant sights, model 1918, used with new materiel and possibly to sights now used with existing carriages.

The changes which are shown in the accompanying photograph, Fig. 5, consist chiefly in the application of an improved method for holding the panoramic sight and the addition of a magnifying lens to assist in reading the elevation scale.

The improved method of holding the panoramic sight consists in the substitution of the socket (B) for the original type of panoramic sight holder. The addition of the socket (B) has been accomplished by cutting off the original panoramic sight stud, threading the upper part of the curved shank (A) and screwing the bracket (B) firmly into place, where it is held by a taper pin. The bracket (B), as indicated, supports the panoramic sight (H) both by its T-lug and by means of the recess machined in the underpart of the panoramic sight body. The panoramic sight is held securely in the socket by the clamp shown, which is provided with a strong spring for holding the sight rigidly in place. This method of holding the panoramic sight is far more rigid than the older methed where the T-lug alone was used, and insures that the panoramic sight will always take the same position.

On account of the fineness of the graduations on the elevation scale of this sight, it was found quite difficult to set the sight quickly and accurately. For this reason the magnifying lens carried by the housing (F) has been added, which increases the apparent size of the graduation to about twice the original size and renders it possible to see the graduations distinctly at the normal eye distance. A spring cover (G) is provided for the protection of the reading lens when not in use.

Watervliet Arsenal Notes

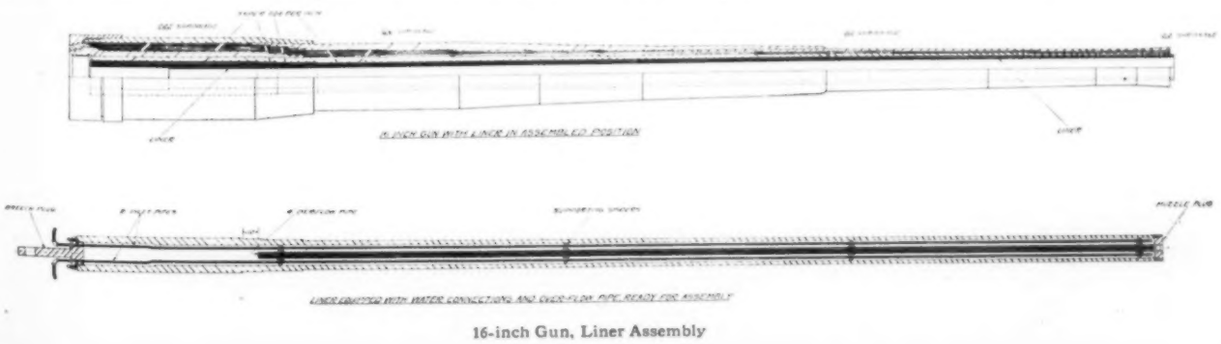
Shrinkage Assembly of Liner in 16-inch 50-caliber Gun.—One of the most interesting operations, as well as one which attracts the most attention in the manufacture of large cannon, is the shrinkage assembly of the inner tube or liner. The liner contains the rifling, powder chamber and gas check seat, the machining of which is generally accomplished after the assembly of the liner although a liner which had the powder chamber machined and the rifling cut was successfuly assembled in a 12-inch gun.

Besides being interesting, the successful assembly of a liner in a large gun presents one of the most difficult problems in gun construction.

The greatest difficulty to be overcome in shrinking a liner in a gun is to prevent excessive upsetting or shortening of the liner with the result that the metal is either in tension or compression, or is either hard on the contact shoulder, or is off the contact shoulder. The shoulder on the liner should be lightly in contact with the shoulder provided in the forging containing the liner seat. If the shoulder is not in contact the liner is liable to move forward and therefore would not serve the purpose for which it is intended. If hard on the shoulder the metal is in compression, and when the gun is fired the liner is liable to have a rearward movement, both of which are to be avoided.

Guns which are originally designed with a liner are built up complete on a tube which is the same length as the liner and is generally known as the "B" tube. The liner is sometimes called the "A" tube. All of the various hoops and rings are assembled on the "B" tube before the "B" tube is reamed to size as the seat for the liner.

The seat for the liner in the "B" tube is conical; the usual taper being about .004 inch on the diameter per inch of length.



16-inch Gun, Liner Assembly

The seat is conical in order to facilitate assembly or disassembly of the liner. Being a cone, the clearance at assembly is a maximum until the liner is dropped to its proper position in the gun.

Watervliet Arsenal has recently assembled a liner in a 16-inch 50-caliber gun, a brief description of which follows:

After the gun has all the hoops and rings assembled in place the "B" tube is carefully reamed to the prescribed size. The bore is then inspected by star gauging every inch in length, the results being carefully recorded to the nearest one thousandth part of an inch. These results are later used in preparing what is known as a shrinkage drawing. This drawing shows the diameter to which the liner is to be turned. The diameter of the liner at any point being the diameter of the corresponding point in the "B" tube where it seats when assembled plus the specified shrinkage.

The gun, which is 68 feet 8.3 inches long, weighing approximately two hundred and seventy-five thousand (275,000) pounds, is now ready for insertion in a large electric furnace, which is provided for raising the temperature of the gun to give the necessary expansion or increase in diameter required to provide clearance for assembly of the liner. The liner diameter is .022 inch greater at the breech end than the diameter of the seat in which it is assembled, tapering to a diameter greater than its seat at the muzzle end of .012 inch.

After the gun is lowered into the furnace the furnace is closed and the temperature is gradually raised to 350° F., approximately ten (10) hours being consumed before the temperature of 350° is reached. This temperature is then held for a period of five (5) hours, when it is slowly and evenly dropped to between 310° and 320° F. This temperature is then held until the time of shrinking, which is usually about nine (9) hours, making the total time consumed in heating the gun approximately twenty-four (24) hours. The temperature to which the gun is heated must be kept as low as possible, as it is desirable that the extension in the length of the gun, caused by the heating, be kept to a minimum, so as to be as near as possible to the length of the liner at normal temperature. The temperature indicated above provides an assembly clearance of .022 inch at the breech end and .02 inch at the muzzle end.

The surface of the liner is carefully turned to the shrinkage drawing. After the liner is turned it is inspected to see that the shoulders are properly located. The diameters are measured every inch in length by means of a micrometer, the results recorded and checked with the shrinkage drawing to see that the results specified have been attained. Dimensions within .001 inch of those specified are required.

The liner is threaded in the breech end, into which is assembled a plug containing two (2) 2-inch water inlet holes. Threaded into the under side of this plug are two (2) 2-inch pipes, which extend downward through the liner to within 2 inches of a muzzle plug, which is also threaded into the liner.

The breech plug provides a means of lifting the liner as well as serving as a water inlet. The muzzle plug is provided with a 4-inch overflow pipe extending upward through the liner to within 12 inches of the contact shoulder. This shoulder being located 10 feet 5 inches from the breech end of the liner.

The liner is now filled with water to the top of the overflow pipe. The exterior surface from the muzzle end to the contact shoulder is lightly coated with a mixture of powdered graphite and oil, care being taken to see that there is not an excess of graphite at any point on the surface of the liner.

For about thirty (30) minutes previous to assembly of the liner four (4) or five (5) gasoline torches are applied to a portion of the liner 6 inches to 8 inches in width located 12 inches to 20 inches from the breech end. Application of these torches is made to increase the diameter of the liner in this zone approximately .01 inch. This portion of the liner is expanded so that it may come in contact with the "B" tube before any other part of the liner does, as it is necessary that the liner be gripped at this point first so securely that it will be prevented being pushed upwards and off the shoulder as the gun forward of the shoulder contracts and grips the liner.

The cross section of the gun along the chase and at the muzzle end being less than the cross section at the breech end cools more rapidly and would ordinarily grip the liner first, causing the liner to be carried with it as the gun shortened in length, thereby raising it off the shoulder if means were not provided to prevent it. The liner being held securely at the breech end, the gun grips the liner towards the muzzle end and slides along the graphited surface. Without the resistance provided at the breech end and with an unlubricated surface, the gun would grip the liner and raise it off its seat.

The liner is now ready for assembly. The cover is removed from the furnace and the liner, which is approximately 67½ feet long, weighing forty-two thousand pounds (42,000), is lifted by a crane and dropped into its seat in the gun; the gun remaining in the furnace. As soon as it is lowered into its proper position, and it is certain that the shoulder is in contact, water is circulated through the two (2) 2-inch inlets for a period of from six (6) to twelve (12) hours.

The water is gauged so that at no time will it rise higher than the overflow pipe. As soon as the liner is assembled the heat is turned off of all sections of the furnace with the exception of the two (2) lower ones which are left on for a period of one (1) hour and twenty (20) minutes. The distance on the gun equivalent to the two (2) lower sections is approximately 10 feet. The idea in continuing the head on the two (2) lower sections of the furnace after the upper ones have been shut off is to prevent the muzzle end of the gun from cooling too rapidly. The tendency of the muzzle end to cool rapidly is greater since the thermal capacity is considerably less due to the decrease in diameter of this part of the gun.

The ideal results in shrinking a liner are of course attained when the temperature of the gun and liner are identical. Since this is impossible due to the difference in diameters we try to approach it as closely as possible, trying to obtain a minimum difference of temperature between the liner and the gun when they come in contact.

The above method of assembly has proven very effective in securing shoulder contact without inducing excessive upsetting of the metal between the shoulder and breech end of the liner, which is liable to occur if the liner is held forcibly on the shoulder by means of a hydraulic jack.

In one of the above paragraphs reference is made to ideal results to be obtained in shrinking a liner. We might now speak of an ideal method. This method would consist in heating the gun to the required temperature as used in the method described—dropping the liner into the gun cold and applying heat to the liner to bring it to the same temperature as the gun. One method suggested by Watervliet Arsenal would be to start at the shoulder, applying heat to the rearward for a short distance, then travel forward of the shoulder applying heat from this point to the muzzle expanding the liner gradually to form contact with the gun.

The idea would be to impart heat to the liner at any desired location as easily as we now extract heat from a hoop at any definite point in making an exterior shrink.

The result obtained in shrinking four (4) 16-inch liners by the method first described are as follows.

Liner off shoulder	.009″ to .004″
Shortening of liner from breech end to shoulder (measured after assembly from location marks indicating the position of the shoulder etched on the interior of the liner when cold)	.002″ to .004″
Total shortening of liner...per inch of length	.3″ to .4″
Total elongation of gun	.003″ to .031″

In a later issue of Army Ordnance there will be a short article describing the method used in removing a worn out liner from a large gun. The removal of a worn out liner is even more interesting than the assembly of a new one as there is liable to be some excitement if the steam generated in cooling is not carefully provided for.

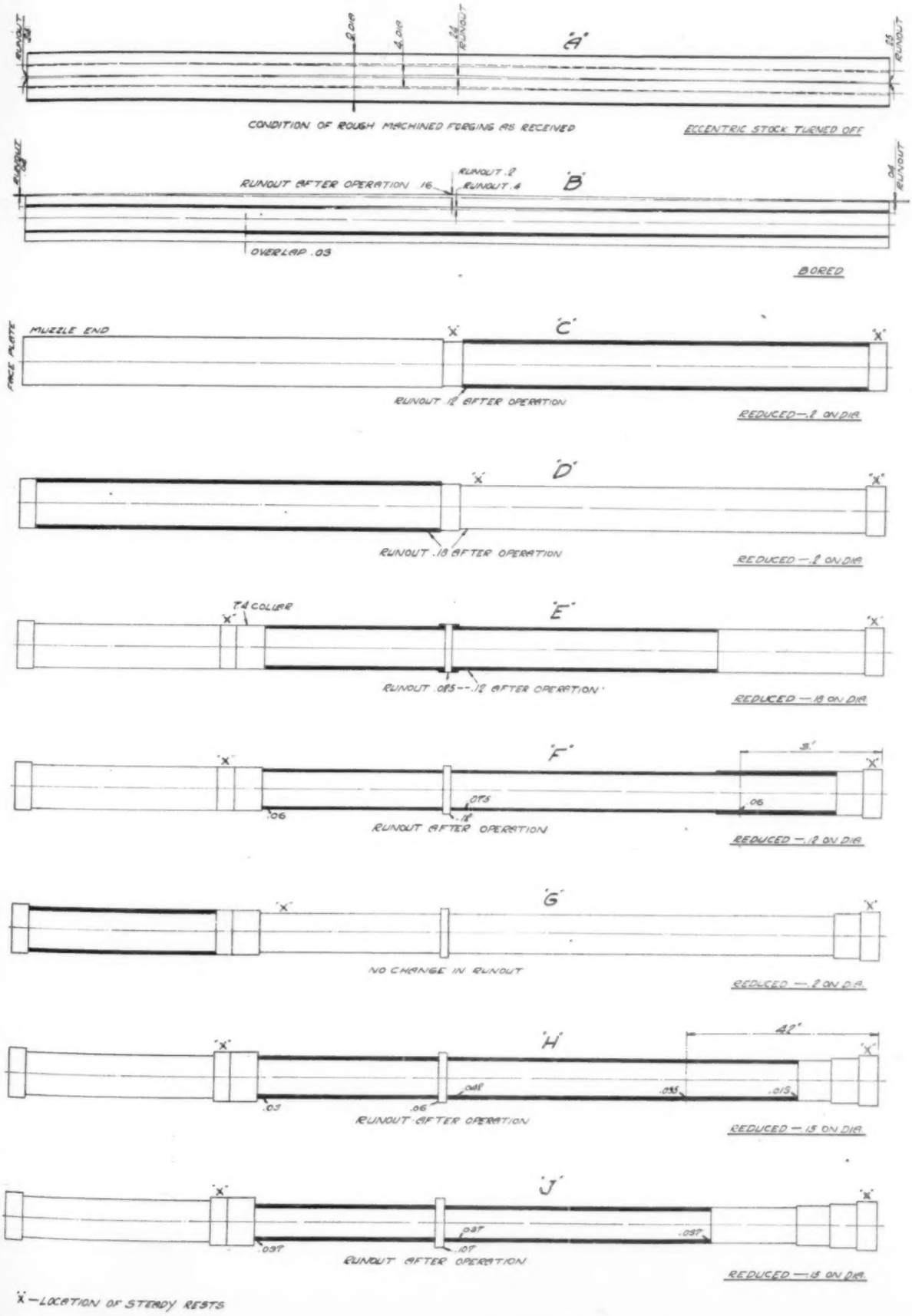
Effect of Internal Strains in Forgings Upon Subsequent Machining Operations.—A striking illustration of the effect of internal strains in forgings set up by quenching from the drawing temperature was recently exemplified at this arsenal in the machining of the tube forging for the 4.7-inch Gun, Model 1920 M1. The test report received with the forging gave the following chemical and physical properties, and heat treatment:

	C.	Mn.	Si.	P.	S.	Ni.	Cr.
	.32	.34	.138	.028	.025	2.90	.44

	E. L.	T. S.	Eln. per cent	Ctn. per cent
Required	65000	95000	18.0	30.0
Actual	86250	107250	18.0	40.3
	88000	108500	19.0	43.3
	86750	108250	18.5	40.3
	86000	109000	18.0	37.2

The physical properties tabulated above were obtained when the forging was heat treated as follows: A triple anneal was

TUBE FORGING
4.7" GUN MOD. 1920 MI



'X' — LOCATION OF STEADY RESTS

the first operation 1000° C. for eight (8) hours, air chilled. 765° C. for eight (8) hours, air chilled. 690° C. for eight (8) hours, furnace cooled. The forging was then heated slowly to 825° C. and held three (3) hours. Quenched in water for two (2) minutes from this temperature. Reheated to 640° C. and held for three (3) hours. Quenched from this temperature in water for one and one-half (1½) minutes.

Upon receipt at this arsenal the forging showed that a cut had been taken across the exterior after heat treating but the bore showed discolorations of heat treatment showing that no metal had been removed from the bore after heat treating.

The forging when received was cylindrical in shape and approximately 9.0″ in diameter with a bore of approximately 4″.

When originally telltaled the bore was found to run out .48″ in the middle with ends of forging held true. The forging was therefore thrown to make the bore at ends run out .24″ and .25″ respectively, leaving a run out in the bore at the middle of .24″ in opposite direction. See sketch ''A.''

In this position the exterior of the forging was running out from .25″ to .3″; the high point on the exterior being on the same side as the high point of the bore run out in the middle and changing position throughout the length of the forging only about 30° on the circumference.

The eccentric stock was then turned off after which the exterior of the tube when released was found to run out approximately .26″ in the middle with ends running true. As the tube in this turning operation sprung in the same direction as the original bow in the bore, the bore was then running out approximately .48″ in the middle (an increase of approximately .24″) and the exterior .26″ in the middle with ends running true. The forging was then thrown to make the bore run out about .4″ in the middle and .36″ at each end in the opposite direction. In this position, the exterior was running out about .2″ in the middle in the same direction as the bore and about .04″ at each end, also in the same direction as the bore. See sketch ''B.''

The forging was then bored to 4.3″ to within four feet (4′) of the middle when the reamer was withdrawn, the bore telltaled and found to run out about .03″. A reamer of 4.37″ diameter was then put into the same depth in order to straighten the bore. The forging was then reversed in the lathe and bored from the other end to meet the first bore—two reamers of 4.37″ and 4.45″ diameter respectively being used. The two bores were found to meet with an over-lap or run out of about .03″. The exterior of the tube when released from the steady rest after the boring operation was found to run out about .04″ less than before the boring operation or actually .16″. See sketch ''B.''

The forging was next rough-turned in the following manner: The muzzle end of the forging was mounted in the lathe chuck and the other end carried in a steady rest without using the dead center in order to permit the forging to expand freely when heated by the friction generated in turning. With the forging running free a steady rest spot was provided approximately in the middle of the forging and a roughing cut removing .2″ on the diameter was taken from the breech end up to the steady rest. When released from the steady rest the surface just turned was found to run out .12″. See sketch ''C.''

The steady rest was next applied on the newly turned surface, holding same true and the cut continued up to the face plate. When released from the steady rest the run out in the middle referred to above had increased from .12″ to .18″ in a direction to improve the .16″ run out existing before the cut shown in Sketch ''C'' was taken. See sketch ''D.''

A new steady rest spot was now made with the tube running free in front of the 7.4″ collar on the tube shown on sketch and a cut removing .18″ on the diameter was taken from a place about 43″ from the breech end up to the 7.4″ collar, a distance of about 100″. A narrow portion about ½″ wide of the steady rest spot which was made in the middle of the forging previous to taking the .2″ cut shown in sketch ''C'' was left undisturbed. After taking the .18″ cut referred to above the narrow portion of the original steady rest spot was found to run out .025″. The new surface near the spot was running out .12″. See sketch ''E.''

The forging was next respotted in front of the 7.4″ collar and a cut removing .12″ of stock was taken from about 1′ from the breech end up to the 7.4″ collar.

When released the narrow collar left in the middle was running out .12″ and the new surface just turned immediately adjacent to the collar .075″; near the 7.4″ collar the run out was .06″ and at the other end of the tube about 3′ from he end the run out was .06″. See sketch ''F.''

The steady rest was next moved to the other side of the carriage and applied about one foot from the 7.4″ collar and a cut removing .2″ on the diameter was taken up to the face plate. When released it was found that this cut did not increase the run out at any point of the tube. See sketch ''G.''

A new steady rest spot was made in front of the 7.4″ collar and a cut beginning about 18″ from the breech end removing .150″ on the diameter was taken up to the 7.4″ collar. Before releasing the steady rest the narrow collar in the middle was noted to run out .09″. After releasing the steady rest, this collar was running out .06″ new surface next to the collar .042″, next to the 7.4″ collar about .03″, 42″ from the breech end .035″ and 18″ from the breech end .013″. See sketch ''H.''

The steady rest was next moved to the other side of the carriage the tube held true by the steady rest close to the 7.4″ collar and a cut removing .12″ on the diameter taken up to the face plate. When released the middle spot was running out .06″ and the new surface next to the spot .042″ same as before.

A new steady rest spot was next made in front of the 7.4″ collar and the surface between the collars reduced .15″ on the diameter in one cut. At the point where this cut was started (42 inches from the breech end) the new surface was running out .17″ by the time the cut had traveled about 26″. When the cut had reached the middle collar the run out at the starting point was .023″. When the cut had reached the 7.4″ diameter collar before releasing the steady rest the middle collar was running out .08″. After releasing the steady rest the starting point was running out .037″, the middle collar .107″, new cut at the middle .037″ and at the end of the cut also .037″. See sketch ''J.''

An analysis of the above operations shows that there was considerable change in the forging after each cut which followed no set rule, indicating that there were severe internal strains.

As the tube had now been roughed as closely to finish size as was permissible under the circumstances and as no improvement was noted as the machining progressed, the tube was returned to the manufacturer for reheat treatment to remove the internal strains. Reheat treatment was as follows:

The forging was heated to 500° C. and held at this temperature for three (3) hours, after which it was allowed to cool in the furnace. The following physical properties were obtained:

E. L.	T. S.	Eln. per cent	Ctn. per cent
88150	114800	16.0	43.3
87750	110300	16.0	40.3
79800	103900	15.0	51.9
78800	105050	15.0	49.1

Inspection of the physical properties obtained showed that the specifications had been met with the exception of the elongation, which was low, denoting that the ducility of the forging was not what it should be. Therefore, the forging was reheat-treated as follows:

The forging was heated slowly to 660° C. and held for three (3) hours at this temperature. Cooled in the furnace. The physical properties tabulated below were obtained from this heat treatment:

E. L.	T. S.	Eln. per cent	Ctn. per cent
76750	98750	18.0	40.3
80000	101250	20.5	49.1
75000	98000	20.0	51.9
75250	99500	19.0	40.3

The inspection of the physical properties obtained showed that the requirements were met and the forging was returned to Watervliet Arsenal where it was carefully indicated to determine whether the reheating of the forging had caused any further distortions and it was found that practically no change whatever had taken place. The machining operations were resumed in the usual manner and no further distortions occurred; the reheat-treatment having relieved all strains which existed in the forging.

A noticeable feature in the machining of this forging was that prior to its retreating the metal machined in a manner similar to cold rolled steel—that is the chips did not have the usual spring the metal appearing to have no life whereas, after heat treating the usual cutting characteristics of this class of steel were apparent.

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Application of Magnetic Analysis to Steel Blanks for Rifle Barrels, Springfield Armory, Mass.

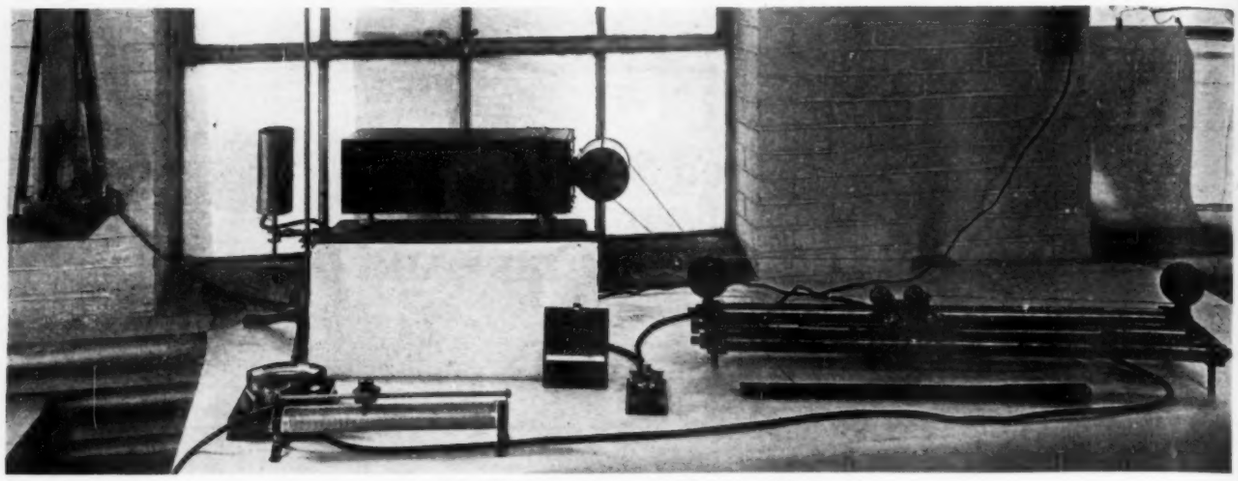


Fig. 1. Magnetic Testing Apparatus for Testing Rifle Barrels

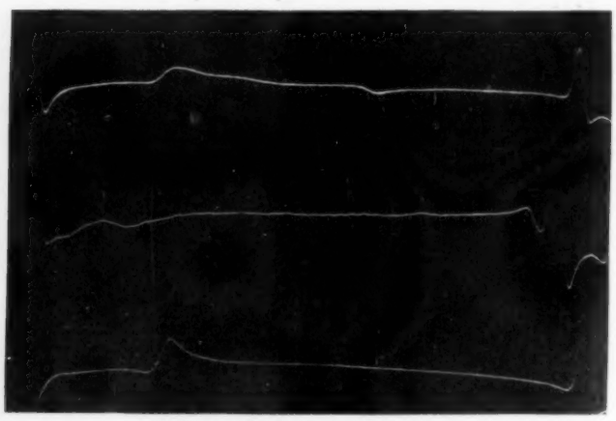
Fig. 1 is a photograph of the magnetic testing apparatus set up for testing barrels. The barrel to be examined is shown held between two sockets in that part of the apparatus at the right of the photograph. The sockets are supported by the two cross members, which are in turn supported by the bars, one on each side of the barrel which also constitute return circuit for the magnetized flux induced in the barrel. The magnetizing solenoid encircling the barrel is supported by the four rollers so that it may be run along the length of the barrel. The test coils are mounted within the magnetizing solenoid and concentric with it. Magnetizing current is supplied to the solenoid by means of a storage battery and regulated by the rheostat and ammeter shown at the left of the photograph. The test coils are connected to the galvanometer, which is mounted on the wall, through the galvanometer key shown in the center of the photograph, hence any electromotive force induced in the test coils will cause a corresponding deflection of the galvanometer. Deflections of the galvanometer are recorded by means of the action of a spot of light reflected from the mirror upon a moving photographic film. This is accomplished by means of the device shown in the center of the photograph which consists of a long, light-tight box upon the right end of which is fixed a standard oscillograph drum which carries the photographic film. The film is rotated by means of the strings and pulleys shown, which are arranged so that the movement of the test coils from one end of the barrel to the other produces a complete revolution of the drum upon which the film is mounted. For visual observation of the deflections of the galvanometer the spot of light is projected on a piece of ground glass instead of on the photographic film.

Figs. 2, 3 and 4 are records made with the aid of the apparatus. Fig. 2 is a record made from a barrel containing no defects. The two large deflections at both ends of the record are due to the end effect, that is the effect of the gap between the barrel and the sockets which hold it. The deflection at the right of the record is due to the change in section and the upsetting of the barrel necessary to form the enlargement at the breech. The form of this deflection is characteristic of all upset barrels.

Fig. 3 is a record made from a barrel which was known to contain longitudinal seams. These seams are indicated by the slight deflections in the left-hand part of the curve and by the change in the characteristic form of the deflection due to the upset end.

Fig. 4 is a record made from a barrel, part of which was intentionally burnt or overheated. The beginning of the burnt section is indicated by the deflection at about one-third of the way along the curve.

While the photographic record shows the deflections due to defects, it is difficult with the present form of apparatus to follow the deflections of the spot of light on the ground glass visually. The deflection due to the upset particularly complicates following the spot of light at that point for this deflection is superimposed on any deflection due to defects which may be present. The apparatus also fails to detect a slag streak which is continuous and uniform in section for the whole length of the barrel.



Records of Galvanometer Deflections
Upper—Fig. 2. Barrel Containing No Defects
Middle—Fig. 3. Barrel Containing Longitudinal Seams
Lower—Fig. 4. Barrel Containing Overheated Section

Allerton S. Cushman
A. M., Ph. D.
(Ex-Lt. Col. Ord., U. S. A.)
In charge of chemical activities and explosive dry houses, Frankford Arsenal, 1917-1918.
Consulting Chemical Engineer and Metallurgist
In charge Industrial Research Laboratories
Reports on metallurgy, coal, petroleum, explosives, dyes, foods, drugs, etc.
1845 B Street, N. W. Washington, D. C.

James A. Drain Dale D. Drain
DRAIN & DRAIN
Attorneys at Law
Wilkins Building, 1512 H Street
Washington, D. C.

Rogers Birnie Wilford J. Hawkins
Birnie & Hawkins
Ordnance and Industrial Consulting Engineers
511 Fifth Avenue New York